The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

Volume 5 Fall 2002

PART I: SPECIAL ISSUE

Virginia Collaborative for Excellence in the Preparation of Teachers

PART II: REGULAR JOURNAL FEATURES

Virginia Mathematics and Science Coalition

The Journal of Mathematics and Science:
COLLABORATIVE EXPLORATIONS

Editor
P N Raychowdhury
Virginia Commonwealth University

Associate Editors

J Boyd
St. Christopher's School

J Colbert
Virginia Tech

N Dávila
University of Puerto Rico

R Farley
Virginia Commonwealth University

L Fathe
George Mason University

K Finer
Kent State University

B Freeouf
Brooklyn College

S Garfunkel
COMAP

J Garofalo
University of Virginia

W Haver
Virginia Commonwealth University

W Hawkins
Mathematical Association of America

R Howard
University of Tulsa

M Leiva
U of North Carolina at Charlotte

J Lohmann
Georgia Institute of Technology

P McNeil
Norfolk State University

G Miller
Nassau Community College

L Pitt
University of Virginia

S Rodi
Austin Community College

D Shillady
Virginia Commonwealth University

S Solomon
Drexel University

M Spikell
George Mason University

C Stanitski
University of Central Arkansas

D Sterling
George Mason University

B Williams
Williamsburg/James City Schools

S Wyckoff
Arizona State University

The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

Volume 5 Fall 2002

PART I: SPECIAL ISSUE

Virginia Collaborative for Excellence in the Preparation of Teachers

PART II: REGULAR JOURNAL FEATURES

Virginia Mathematics and Science Coalition

The Journal of Mathematics and Science:
COLLABORATIVE EXPLORATIONS

Volume 5 Fall 2002

PART I: SPECIAL ISSUE

Virginia Collaborative for Excellence in the Preparation of Teachers

Virginia Mathematics and Science Coalition

THE VIRGINIA COLLABORATIVE FOR EXCELLENCE IN THE PREPARATION OF TEACHERS

R.W. FARLEY and W.E. HAVER
Dept. of Mathematics and Applied Mathematics, Virginia Commonwealth University
Richmond, VA 23284-2014
rwfarley@vcu.edu, wehaver@vcu.edu

The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) is a joint undertaking of a group of Virginia colleges and universities to improve all aspects of their programs to prepare individuals to teach mathematics and science in grades K-8. Major funding for the work to improve the teacher preparation programs was provided by grants totaling more than six million dollars from the Collaboratives for Excellence in Teacher Preparation (CETP) program of the National Science Foundation (NSF) that supported work from May 1996 through October 2002. The NSF has also funded a three-year, follow-on component featuring a support process for new VCEPT teachers and long term program evaluation. The core four-year institutions were Virginia Commonwealth University, Norfolk State University, Mary Washington College, and Longwood University. Participating two-year colleges included Germanna Community College, Tidewater Community College, and J. Sargeant Reynolds Community College. The Mathematics & Science Center of the central Virginia school systems served as the major link to schools and teachers, and the Virginia Mathematics and Science Coalition (VMSC) served as VCEPT's Policy Advisory Board. Midway through the project the University of Virginia, the College of William and Mary, and Virginia Union University formally associated themselves with VCEPT.

Through VCEPT, the core institutions each dramatically, and for the long-term, improved all aspects of their K-8 math/science teacher preparation programs. In addition, improvements have taken place in programs at many other Virginia institutions, and policy changes have taken place that have transformed teacher preparation programs throughout Virginia and beyond. Some of the results of VCEPT are described in this introduction, and in reports on a sample of VCEPT's work that are included in this Special Issue.

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 1- 7

The work of VCEPT took place in the following areas: policy; courses; in-school experiences; recruitment and retention; and, cross-fertilization, dissemination and evaluation. The papers selected to appear in this Special Issue report on samples of this work, and are briefly described in this introduction.

Policy

As VCEPT's Policy Advisory Board, the VMSC was a key partner in bringing about changes in policy. Policy changes occurred in a number of areas.

Mathematics and Science Requirements for Prospective K-6 Teachers — Prior to VCEPT, there were no specific state requirements concerning the number of mathematics and science credit hours to be completed by future elementary school teachers. Many teacher preparation programs required only a total of six credits in mathematics and science, and VCEPT colleges required little more. Our first step was to change requirements of VCEPT colleges; then, a major initiative was mounted to change state policy. State policy for alternate licensure and expectations for approved programs now include a total of 24 hours of mathematics and science for the K-6 license.

Requirements for Future Middle School Teachers — Before VCEPT, individuals could be fully certified to teach middle school mathematics and science by virtue of having the equivalent of a minor in language arts and a minor in social studies. As confirmed by a study commissioned by VCEPT and VMSC [1] the majority of Virginia's mathematics and science teachers do not have the equivalent of a minor in their field. All Virginia colleges combined were producing an average of twelve new middle school teachers a year with the equivalent of a minor in mathematics or science. As a direct result of VCEPT and VMSC policy efforts, new middle school teachers must now have the equivalent of a minor in the area they teach. VCEPT colleges have developed new programs to prepare these teachers.

Role of Community Colleges in the Preparation of Teachers — Before VCEPT, the important role of community colleges in the preparation of teachers was not recognized in Virginia. Very few two-year colleges offered any courses or programs designed to prepare future teachers and there was little recognition of the fact that 40% of future teachers completed some or all of their mathematics and science in two-year colleges. At the request of the NSF, VCEPT played a key role in planning and conducting a national workshop, *The Integral Role of the Two-Year College in the Science and Mathematics Preparation of Prospective Teachers* [2]. The local planning committee was led by VCEPT participants Debbie Fisher and Susan Wood of J. Sargeant

Reynolds Community College. The report of this workshop has had a major impact nationally and within Virginia, and was instrumental in the creation of a Virginia community college system-wide Taskforce on Teacher Preparation. The Taskforce created two PRAXIS preparation courses, and an *Introduction to Teaching as a Profession* course. These courses are now offered statewide in colleges which previously had no presence in teacher preparation. Teresa Galyean and Susan Wood, who co-chaired the Taskforce, were formally recognized by VMSC in September 2002 for their achievement among "Programs That Work."

Courses

The change in policy requires future teachers to study significantly more science and mathematics, but even more important than the quantity is the nature and quality of the coursework taken by prospective teachers.

At its inception, VCEPT faculty agreed on a detailed set of general criteria for all courses to be developed. In summary, the VCEPT criteria expects that the courses should: enhance active student learning; assist students to make connections with other disciplines; make use of appropriate teaching methods and technologies; provide students with an understanding of state and national standards; and, engage students in a variety of assessment situations.

A total of more than sixty courses exhibiting these criteria have been developed and offered at VCEPT institutions and are described on the VCEPT web page [3].

General Education Courses — VCEPT faculty are convinced that courses satisfying the VCEPT criteria are not only appropriate for future teachers, but provide the best education for all students. One such biology course offered at Virginia Commonwealth University is described by Joseph Chinnici in "A Model General Education Science Course Involving Humanities and Sciences, Education, and Medical School Collaboration." A mathematics general education course at Mary Washington College that was designed to meet VCEPT criteria is described by Debra Hydorn in "Enhancing Finite Mathematics with Global Awareness." A physics course and a chemistry course designed at Norfolk State University to meet the needs of future teachers, but also serve as exemplary general education courses, are described by S. Raj Chaudhury in "The Science Studio—A Workshop Approach to Introductory Physical Science" and H. Alan Rowe in "The Use of Dramatic Demonstrations to Enhance the Motivation and Learning of Chemistry Students." In "Mathematics for a Non-Science Majors Chemistry Course," Don Shillady of

Virginia Commonwealth University describes *Chemistry in the News* as being designed especially for future teachers, but also recommended for all general education students.

Courses Offered Primarily for Teachers — In "Case Studies from an Integrated Mathematics and Science Course," Phillip McNeil describes an interdisciplinary mathematics and science course offered by Norfolk State University that is particularly appropriate for teachers. William Haver and Joseph Chinnici adapted this course and have offered it four times for future elementary and middle school teachers at VCU. VCEPT has recognized the importance of geometry for teachers. In "Revision of a Non-Euclidean Geometry Course Based on the van Hiele Model of the Development of Geometric Thought," Marie Sheckels describes a geometry course offered at Mary Washington College that is designed for future middle and high school teachers. Loren Pitt has taken the lead within VCEPT in developing and offering geometry courses for future elementary teachers. The course he describes, "Thinking about Geometry: Laying a Foundation for Future K-8 Teachers," is offered at the University of Virginia and has been adapted for use at five other Virginia colleges. All VCEPT courses enable future teachers to gain competence with technology. A major focus on enabling future teachers at Virginia Commonwealth University to learn science and gain skills with advanced technology is described by Robert Fisher, Jonathan Ha, and Joseph Chinnici in "Integration of Technology in Math and Science Education—A Model for Teaching Elementary and Middle School Pre-Service Teachers."

Methods Courses — Mathematics, science, and education faculty worked together on a VCEPT taskforce to support each institution's efforts to improve its mathematics and science methods courses. At Virginia Commonwealth University, the focus was on adding the use of appropriate technology to the existing efforts. Johnny Johnson and Laura Wilkowski report in "Using Technology Within the Teacher Preparation Program as a Model for Effective Instruction" on the impact of adding the use of technology to science methods courses.

In-School Experiences

A key component of VCEPT's effort is the development and institutionalization of programs to make a major improvement in the in-school experiences of new teachers. In "The Impact of a Clinical Faculty Institute on Participants' Skills for Mentoring Novice Teachers, Grades K-8," Julia Cothron, Executive Director of the Mathematics & Science Center, and George Bass, VCEPT evaluator, describe the Clinical Faculty Institutes that prepared outstanding teachers to enhance experiences for new teachers. Each VCEPT institution is making extensive use of these newly trained Clinical Faculty.

Early Experiences in Schools — Many VCEPT colleges did not have mechanisms to provide future teachers with opportunities to be actively involved in the schools until late in the college programs. Taking advantage of the relationships developed with Clinical Faculty, various VCEPT institutions provided opportunities for freshmen and sophomores to work in after school tutoring and mentoring programs. Diane Simon described the VCEPT-supported Project BEST [4]. VCEPT also provides students with opportunities to observe and participate in classes during the regular school day. Gayle Childers, of J. Sargeant Reynolds Community College, describes such a program in "A Collaborative Pre-Practicum Apprentice Program Gives a Community College a Jump-Start in Teacher Preparation."

Recruitment/Retention

VCEPT's major recruitment/retention tool is an extensive apprentice teacher program. The recruitment effort focuses on increasing the number of African-American future K-8 teachers; the number of male future K-8 teachers; and, the number of future K-8 teachers with extensive interest and course work in mathematics and science. Coupled with the Pre-Practicum Apprentice Program mentioned above, these experiences served to introduce prospects to a realm of teaching activities and thereby attract them to the profession.

Apprentices in College Courses — Many of the prospective future teachers served as teaching apprentices in newly developed VCEPT general education courses. One example of the use of apprentices is described by Joseph Chinnici in "A Model General Education Science Course Involving Humanities and Sciences, Education, and Medical School Collaboration."

Tutoring and Mentoring — As described in the previous section, the opportunity to have contact with students and classrooms proved to be a powerful recruitment tool. Grant funding provided minimal student wages for these activities.

NSF Teaching Scholars — Based on their interest and potential in mathematics and science teaching, 250 NSF Teaching Scholars were selected at VCEPT institutions. These teachers were supported by NSF funding of a half million dollars over five years and were recognized at special VCEPT ceremonies.

Cross-Fertilization/Dissemination/Evaluation

In our view, the extensive impact of VCEPT is due to a large degree to the extensive cross-fertilization, classroom visitations, collaborative course evaluations, and collegial colloquia that occurred throughout the funding period.

Summer Institute — Each year, a Summer Institute was offered featuring college courses developed with VCEPT support. Rotating Institutes were held at Virginia Commonwealth University, J. Sargeant Reynolds Community College, Norfolk State University, Mary Washington College, and Longwood University. Each course was team-taught by faculty from at least two VCEPT institutions and by teaching apprentices or Clinical Faculty. The courses described in this special issue by Phillip McNeil, Raj Chaudhury, Alan Rowe, Johnny Johnson and Laura Wilkowski, Don Shillady, Debra Hydorn, and Loren Pitt were each visited during at least one Summer Institute. Altogether, at least 500 structured visits to approximately 35 VCEPT courses took place during the duration of VCEPT.

Evaluation of VCEPT Courses — Each VCEPT course is visited on an extensive basis; a detailed description of each VCEPT course and a description of the extent to which the course meets the VCEPT criteria for course development is described on the VCEPT web page [3]. In "Evaluating Reform Teaching in College Courses—Action Evaluation is Action Research," George Bass describes the external evaluation of the courses.

Dissemination — The major unfinished business of VCEPT is to respond to the fact that Virginia's colleges are still not producing the needed number of future middle school science and mathematics teachers. We have received a grant from the Fund for Improvement of Postsecondary Education of the United States Department of Education to enable ten Virginia colleges and universities to expand and improve our middle school teacher preparation programs. This effort is described on the program website and features exchange visits by paired teams from the member colleges and universities to disseminate successful program aspects statewide [5]. This expanded group of initial VCEPT institutions will work together toward the goal of producing many more well prepared middle school mathematics and science teachers.

VCEPT Follow-On Project — The three-year follow-on project began in 2001 with a dual focus. First, special mentoring support is provided to novice teachers trained through the VCEPT programs at partner institutions. These teachers who are entering the profession are paired with

VCEPT trained Clinical Faculty for mentoring and are provided stipend support aimed at involving the teachers in professional meetings, conferences, and additional professional development opportunities. The second focus involves classroom evaluation of these new VCEPT teachers under the direction of George Bass, the VCEPT evaluator, in an attempt to measure the effectiveness of the VCEPT program in preparing mathematics and science teachers. This evaluation will be integrated into an overall NSF evaluation of its CETP program.

Conclusion

On behalf of VCEPT, we would like to acknowledge and express our appreciation for the support provided by the Division of Undergraduate Education of the National Science Foundation. Without this support, the extensive improvements to our teacher preparation programs would not have occurred. The articles in this Special Issue section represent only a small portion of the work accomplishments of VCEPT, but we believe it to be a fair depiction of the work of the Collaborative. ■

References

[1] *Preparing Middle School Mathematics and Science Teachers: A Challenge for Virginia*, Virginia Mathematics and Science Coalition, White Paper, May 1999.

[2] *Investing in Tomorrow's Teachers: The Integral Role of Two-Year Colleges in the Science and Mathematics Preparation of Prospective Teachers*, National Science Foundation, NSF-9949, 1998.

[3] Virginia Collaborative for Excellence in the Preparation of Teachers Website, http://vcept.longwood.edu/

[4] D. Simon, "Project BEST: A Collaborative Program to Recruit Teachers and Enhance Science Performance of Middle School Students," *The Journal of Mathematics and Science: Collaborative Explorations*, **3**(2) (2000) 23-30.

[5] Preparation of Middle School Mathematics and Science Teachers in Virginia Website, http://www.math.vcu.edu/Preparation_of_middle_school_teachers/

THE SCIENCE STUDIO—A WORKSHOP APPROACH TO INTRODUCTORY PHYSICAL SCIENCE

S.R. CHAUDHURY
BEST Lab/Dept. of Physics, Norfolk State University
Norfolk, VA 23504
schaudhury@nsu.edu

Abstract

This paper describes the Science Studio, an innovative workshop approach for instruction in a physical science course that combines aspects of traditional lecture and laboratory. The target audience for this introductory course is non-science majors, including prospective teachers. An inquiry-based, technology-rich learning environment has been created to allow students hands-on, in-depth exploration of topics in physics, and earth and space science. Course philosophy, course development, and sample activities are described in this paper, along with outcomes from a project-wide evaluation of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), an investigation of change in student attitudes and the lasting impact of the studio model at Norfolk State University.

Introduction

There has been an extensive body of work over the past twenty years documenting the shortcomings of traditional modes of instruction at improving the learning of physics at the introductory level [1]. The concept of the Science Studio arose from a decade-long movement within the physics education community to create a rich, alternative learning environment for students that mirrored more closely the process of scientific exploration as practiced by experts. Leaders in this field were Jack Wilson at Renssalear Polytechnic Institute (Studio Physics) [2] and Priscilla Laws at Dickinson College (Workshop Physics) [3]. The defining characteristics of workshop/studio physics classes are an integrated lecture/laboratory format, a reduced amount of time devoted to lecturing, a technology enhanced learning environment, collaborative group work, and a high level of faculty-student interaction. The learning environment employs inquiry activities, computer tools, and multimedia materials that allow students to actively participate in their own learning. A high priority is placed on allowing students to learn directly from their interactions with the physical world through "hands-on" activities. However, the Renssalear Polytechnic Institute (RPI) and Dickinson courses were designed for the calculus-based introductory physics course and there was a clear need for the approach to be applied to the non-science majors physics or physical science course. The Dickinson College group started work on the Workshop Physical Science curriculum, now being published by John Wiley and Sons as *Explorations in Physics* (2002), at around the same time that the Science Studio concept was being formulated at Norfolk State University (NSU) in the mid-1990s.

Motivation

The Science Studio was initially offered as a pilot section of *Physical Science 100*, a course in the Department of Physics, which helps satisfy the University's general education science requirement. Most students who enroll in *PHY 100* are non-science majors, with about 30% intending to seek teacher certification. The course was structured as a 3-credit hour lecture with an optional separate 1-credit hour laboratory course. As a service course, it remains very important to the department, but little assessment data existed to indicate whether the course was effective in enhancing student comprehension of the process of science or whether student attitudes toward science were positively impacted by enrollment in either lecture or laboratory sections. In addition, due to the separated credit, there was no coordination between topics covered in lecture and those covered in the laboratory course and more importantly, students were often not enrolling in the lecture and laboratory sections in the same semester. The recent literature on the teaching and learning of physical science points toward active engagement strategies and guided-inquiry techniques as having the most success in fostering student learning of difficult, abstract concepts embodied in the physical sciences [4,5]. If students take the lecture and laboratory sections in different semesters, it is of course very hard for them to make connections between theoretical and applied portions of the course. The Science Studio was designed to address this barrier to student learning by eliminating the separation of lecture and laboratory.

Another motivating factor for this author was a desire to continue research on student learning using advanced technologies (such as Microcomputer Based Labs [MBL] and Video Based Labs [VBL]), on which some studies had been published in the literature, but none had been completed at a minority institution [5,6,7]. The emergence of instruments such as the Views About Science Survey from Arizona State University [8] afforded the opportunity to evaluate the course not only on the cognitive level, but also in the affective domain.

Goals

The goals of the Science Studio project are in line with the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) criteria for course development. It is expected that successful Studio participants would have:

- increased their scientific literacy and improved their critical thinking abilities;
- acquired mastery of a diverse subset of physical science concepts;
- improved their skill and confidence level using communication technologies, including computers and multimedia;
- increased their ability to read graphs and interpret their meaning;
- developed more positive attitudes toward science.

In addition to these general education goals appropriate for all students, the course was designed to enable pre-service teacher candidates a chance to acquire skills and knowledge they could pass on to their own students in the K-12 classroom. This goal is becoming increasingly important in view of national and state accreditation agency policies that require teacher preparation colleges to demonstrate that their graduates are contributing to student achievement in the K-12 classroom.

Scheduling

Two separate sections of the Studio have typically been offered—one for students in the University's Parsons Academic Honors program and another that is open to all students. On occasion, due to low enrollment, students in the Honors section have been combined with the "regular" section. There was no difference in the instructional approach taken with these two groups of students. While the Honors students were observed to be more motivated to complete assignments and clearly possessed higher-order communication skills, their class attendance was not manifestly different from other students enrolled in the Studio (average 70-75% attendance). To facilitate the Studio model without creating a new course, students were required to sign up for *both* the 3-credit hour (CH) lecture course (*PHY 100*) and the 1-credit CH laboratory course (*PHY 100L*) which was scheduled to immediately follow the lecture section. These courses were listed separately in the course schedule booklet, and both were shown to be taught by the author of this paper.

The Studio was scheduled to meet for two and one-half hours each on Tuesdays and Thursdays to give a total contact time of five hours, equal to the three hours of lecture plus two hours of laboratory in a traditional model. However, the University's registration system did not permit the department to ensure that the *same* group of students was enrolled in both the "lecture" section and the "laboratory" section of the Studio. This lack of coordination resulted in mass confusion during the first few class periods, as students sorted out the unusual constraint of being required to have the same instructor for both lecture and laboratory and being required to enroll in the lecture and laboratory in the same semester! With departmental cooperation, the Studio was scheduled to meet in a laboratory room almost exclusively reserved for this purpose. This allowed student experimental setups to remain assembled in between class meetings and greatly facilitated course logistics.

The Studio Environment

Average enrollment in the Science Studio was 12-18 per semester over a four-year period with one instructor. On a few occasions, a student assistant has worked with the author. In each case, the assistant was a graduate of the course, interested in teaching, comfortable with technology, and able to lead group discussions. Six "stations" were available—each comprised of a relatively fast computer, data acquisition equipment (see below) and appropriate software packages. On occasion, students have had to work in groups as large as four, but the typical size has been two or three. Students are encouraged to form groups right away, but due to the fluid nature of enrollment in an introductory non-majors' course (and the scheduling issues with the Studio described above), group size and composition rarely stabilized until after the fourth class period.

From this author's experience, a class size greater than 24 would be unmanageable for one instructor. For any group larger than ten, the presence of a laboratory assistant would greatly facilitate student learning, as intensive demands are put on instructors in a Studio session. The Studio is inherently constructivist in nature and it is important to guide students' thinking rather than giving them the answer via a lecture (the latter being more efficient for the teacher). Students with prior experience in physical science often use words such as "force," "velocity," and "acceleration" to answer questions on mechanics concepts with only a superficial understanding of how to apply them. The hands-on nature of Studio activities (described below) requires students to connect these terms with real-world data they are collecting and requires instructors to constantly engage in Socratic dialog with students to ensure they successfully do so. The Science Studio has only been taught by one instructor so far at NSU (the author) because special training/exposure is necessary to develop the attitude and skills this instructional model demands. Further details on instructor preparation are provided later on in this article.

Data Acquisition

From the various commercial options available for real time data acquisition equipment, the Personal Science Laboratory (PSL) from TeamLabs was chosen for the Studio. There were two reasons for this: (1) the PSL equipment is rugged and built to withstand the company's principal users who are in K-12 classrooms; and, (2) they offered the Windows-based *Excelerator* software for acquisition, control, and analysis which is an application add-on for *Microsoft Excel*. Thus, students familiar with *Microsoft Office* environments would not have to learn any additional user interfaces to use the basic features of the probeware software—a significant advantage. A PSL "station" typically comprises a computer (optional Internet connection), an analog-to-digital converter (connected to the computer via serial or USB port), various sensors (ultrasonic distance probe, force probe, temperature probe, etc.) and other supporting laboratory equipment, such as Pasco dynamics carts, air tracks, pulleys, glassware, etc., as needed.

Studio Curriculum

The approach to curriculum design in the Studio was informed by research on student learning in the sciences and by the concurrent development of instructional materials in the Workshop Physical Science project, *Physics By Inquiry* [9], from the University of Washington group and by the American Association of Physics Teachers' (AAPT) *Powerful Ideas in Physical Science* [10]. All these approaches emphasize limiting the number of topics covered in the course to allow students to build robust mental models of a select few natural phenomena. For the NSU Science Studio, the course topic sections were: "Motion and Mechanics," "Solar System," and "Seasons." Students working in small groups completed guided activities in each of these areas. Approximately eight weeks were spent on mechanics and the other half of the semester divided equally between space science and climate change.

An appropriate textbook did not exist for the Science Studio. The author compiled a collection of instructional materials, multimedia resources, and Internet sources that was provided to the students free of charge. Many of these items were purchased with grant funds or obtained through the author's collaborative relationships with curriculum developers and continue to be available for student use in *PHY 100*. In the current era of custom electronic publishing being promoted by many textbook publishers, it should be possible to compile appropriate instructional resources from multiple sources and make it available through the campus bookstore at a cost no greater than that of a traditional textbook for physical science. The materials used in the Studio are provided in the references.

After completing several guided-inquiry activities, students designed their own Motion Experiment as a group project and made a formal presentation to their peers using *PowerPoint*. Approximately 50% of the course grade depended on the student successfully completing classroom activities throughout the semester, 25% was based on group project(s) that typically required several hours outside the classroom, and 25% of the grade was based on quizzes and tests. Since group projects and activities can be adversely affected by the absence of certain members, the grading scheme for many Studio activities had equally weighted portions for group and individual achievements. As mentioned earlier, the attendance has averaged 70-75% over the four years that the Studio course has been offered, often a hindrance to group completion of activities on time.

While working on their group projects, students invariably ran into all kinds of problems they had to solve. These problems ranged from deciding on when the group would meet (no mean feat since many NSU students juggle school, a job, and family) to trying to figure out how to apply their classroom knowledge to a new situation. In short, they were put in a very real-world situation in which they had to work with other people to produce something by a specific deadline. The experiences gained through this aspect of the course were valuable life lessons, even though they did not appear as learning objectives in the course syllabus.

Motion and Mechanics

Exploration of topics in motion utilizing kinesthetic approaches, as made popular by Laws [11], Thornton and Sokoloff [6], and others, played an important part in this section of the course. Special emphasis was placed on learning the mathematics of change from position versus time graphs generated by the probeware system. Non-science majors often have minimal mathematics preparation, yet it is important, especially for the pre-service teachers, to see the connection between real-world phenomena and the mathematical language in which they can be described. A typical set of graphs that have been used on numerous occasions on tests in introductory courses is shown in Figure 1 below, along with a set of questions that requires a working knowledge of slopes, and helps students demonstrate their comprehension of an *operational definition* of the fundamental quantities involved in the study of motion. While no formulae appear, mathematical rigor has not been sacrificed. Learning activities adapted from the Workshop Physical Science and TeamLabs curriculum guides comprise the MBL experience for students in the Science Studio. Desktop digital video has been available as a tool for education

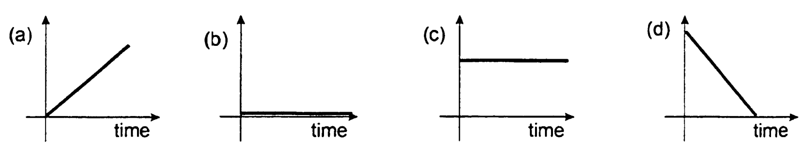


Figure 1

Question 1. The professor walks at a steady pace from one end of the room to the other. If we measure his distance from the starting point, which graph best shows how his POSITION changes as a function of time? (i.e., POSITION is being plotted on the vertical axis).

Question 2. For the motion described above, which graph below shows how his VELOCITY changes as a function of time? (i.e., VELOCITY is being plotted on the vertical axis).

Question 3. For the motion described above, which graph below shows how his ACCELERATION changes as a function of time? (i.e., ACCELERATION is being plotted on the vertical axis).

for over ten years. A variety of low-cost systems now make it extremely affordable to allow students to take their own video footage of an interesting phenomenon in the world and use graphical analysis software to analyze it frame-by-frame [7,12]. In the Science Studio, two computers are outfitted with Intel Smart Video Recorder III cards, which enable the capture of video onto disk from a camcorder. The software tool that has been used in the Studio is *VideoPoint* [13] that allows extensive analysis of video data.

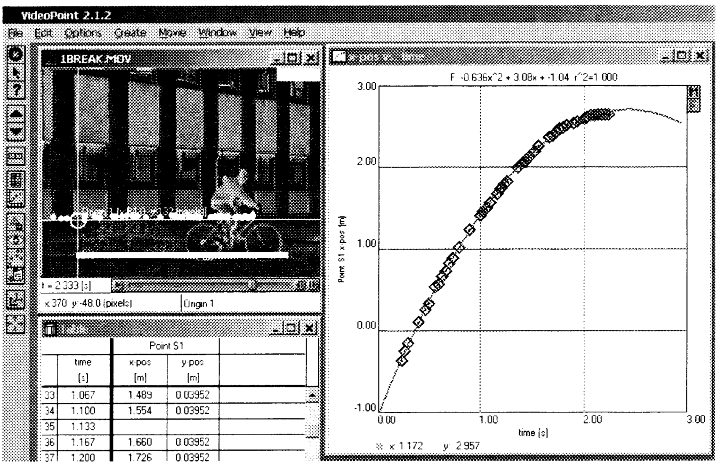


Figure 2

In the screen shot from *VideoPoint* shown in Figure 2, the video window (top left) has been color-inverted to bring out the image contrast. The video shows a student riding a bicycle across a predetermined distance (thick white line in video). On each frame of video, the location of the handlebars (picked for convenience) is marked. These show up as white dots on the Figure. The rider entered the camera view at a constant speed and then applied the brakes, stopping at the last white dot. The thick white line represents a known distance, marked on the ground by soda bottles, which is used to convert screen pixel distances to units of meters (the ruler tool in *VideoPoint* is used for this).

Once the student has marked with a mouse the location of the chosen point in each frame of video, a graph of x-position versus time is constructed. With the origin of the graph chosen to coincide with the start of the predetermined riding distance, a simple curve fitting routine built into *VideoPoint* is applied to determine the best fit. Students then compare this fit to the known kinematic equations of motion and can extract such information as initial velocity, acceleration, total time of travel, etc. Students contrast graphs of uniform motion with non-uniform motion in terms of the slope. They are able to build on and solidify their previous experience with MBL graphs. The decreasing slope in the case shown here would indicate the rider is *slowing down*.

An important feature of this activity, related to student affect, is that they not only collect their own data, they actually *create* their own data by taking a video of one of their group members riding the bicycle. VBL activities have been a very popular choice for group projects. Some subjects chosen for analysis were "basketball three point shots," "trampoline jumps," as well as, "the behavior of mechanical toys."

Solar System

While most college students can recite the names of the nine planets, the size and scale of objects in the solar system pose problems for them. The Science Studio students entered the course with misconceptions that were no different from the vast majority of non-science majors taking an introductory astronomy or physical science course. At NSU, students were asked to submit hand drawn sketches of their concept of the solar system, with as much detail as they were able to provide. This elicitation activity gave the instructor some insight into the initial state of students' mental models and a sense of how large the knowledge gaps were.

To help students build a picture of the solar system that more accurately represented the current state of knowledge, a variety of sources were used. Initially, the Studio was not wired for Internet access, so CD-ROMs produced by NASA [14] and clips from a Physics Cinema Classics videodisc were used to guide student learning. Students built an appreciation of orbits, relative sizes of planets, and a true understanding of the components of the solar system. For instance, students often think that the millions of stars visible in the night sky are actually part of the solar system (a preconception that was illuminated by the elicitation activity and one that largely disappeared as measured by post-instruction assessment). When scheduling permitted it, students took a virtual reality tour of the solar system using advanced Silicon Graphics workstations in the NSU scientific visualization lab.

Reason for the Seasons

The final section of the Studio was based on the question, "Why is it warmer in the summer and colder in the winter?" This question was made famous by the "Private Universe" video [15] that showed Harvard University graduates unable to give a correct scientific explanation of the reason for the seasons. At NSU, an elicitation question opened the discussion of this topic, with results similar to the Harvard experiment [16]. A short excerpt from a student paper follows:

> It is warmer in the summer because of the rotation of the earth and the relativity to the sun. The (distance) between sun and the earth is shorter [the student used units of light years on his diagram to indicate this], meaning an increase in temperature. It is colder in the winter due to rotation as well...and results of winter and summer are attributed by the tilt of the earth as well.

Clearly this student knew terms such as "rotation," "relativity," "light years," and "tilt of the earth," but did not know how to use them to explain the phenomenon of seasons.

Two innovative software tools have been used in the Studio to help students learn about the seasons (and lead into a topical discussion of greenhouse effect and global warming). A simulation program called *Seasons* [17], from Riverside Scientific Software, allowed students to change the distance of the earth from the sun and the tilt of the earth's axis to observe temperature variations at multiple locations on the earth. Students then used a scientific visualization software tool called *WorldWatcher* [18], developed at Northwestern University to create false color maps of global temperature distributions obtained from satellite measurements and compare quantities, such as total amount of energy received in each hemisphere during summer or winter months. Students completed learning activities to gain an appreciation for the role of the earth's axial tilt in seasonal changes—leading to more intense sunlight, longer daylight hours and a net shift in the energy balance between summer and winter. Since the global scale of these phenomena is hard to reproduce in the laboratory, the interactive software tools provided students an environment in which they could interact directly with the relevant physical variables and further refine their observation, analysis, and communication skills.

Course Assessment and Evaluation

Student performance in the Science Studio as measured by grade distribution has not been substantially different from lecture sections taught by the instructor. While attendance is a critical component of student success in the Studio, general education courses not in their major field are often given short shrift by students. Thus, student attendance issues affect all sections of *PHY 100*. While the Studio model definitely succeeds in engaging students, it has not made a significant difference in either student attendance or final grade distribution. The most interesting outcomes of the Studio have been with regard to student attitudes toward science and this is described further in the sections below.

Student Attitudes

In Spring 1997, an attitudinal survey based on the Views About Science Survey (VASS) [8] was given at the beginning of the semester to 200+ *PHY 100* students across multiple course sections. Included in this group were the Studio participants as well as 70+ students enrolled in a "traditional" lecture section taught by the author. The Studio curriculum was very similar to what has been described above, while the lecture course followed the standard textbook and covered a wider variety of topics. Every effort was made to bring interactive, visual demonstrations into the lecture, including NASA images, MBL, and clips from videodiscs. A teaching assistant facilitated course logistics in both the traditional section and the Studio section.

The VASS uses a Contrasting Alternate Design (CAD) and asks respondents to choose a degree (1-7) of agreement between two extremes (a) and (b) of an issue: e.g., "Learning physics requires (a) a serious effort OR (b) a special talent." Students choose (1) if they agree with the (a) statement and (7) if they agree with the (b) statement, or a number in between if some middle ground between the two contrasting statements fits their views. Typically, one of the statements could be associated with scientific expertise while the other with a naïve, folk view of science. The NSU attitudinal survey, modified and simplified to aid the research, was administered to 125 *PHY 100* students at the end of the semester (including the author's lecture section). For validity checking, the Studio students completed the full VASS. The VASS classifies responses as either being expert (the professional scientists' view of the importance and relevance of science), folk (a novice's view of science), or mixed (having features of both expert and folk). At the beginning of the semester, the Studio students had views similar to the rest of the student body surveyed. The results from the post-survey clearly indicated that regardless of instructor, students enrolled in the traditional lecture did not shift their views about the importance or personal relevance of science. On the other hand, the Studio students (who completed the full VASS) *appreciably shifted toward expert views* on a number of VASS dimensions. While it was personally disappointing for the author that the attitude of his lecture section students shifted no more than that of his colleagues, the power of the Studio model to change student attitudes emerged from this study [19].

VCEPT Evaluation

In Fall 1999, the Science Studio participated in the VCEPT project evaluation [20]. Students used a five-point rating scale to describe the *presence* and *value* of course characteristics as shown in Figure 3.

To what degree did the classes in this course include...	To what degree are these course characteristics important in helping you learn in this course...
A = Systematic Use (100% of classes) B = Customary Use (75-99% of classes) C = Frequent Use (50-74% of classes) D = Moderate Use (25-49% of classes) E = Occasional Use (0-24% of classes)	A = Very Important B = Important C = Unimportant D = Detrimental to your learning E = Not Applicable or No Opinion

Figure 3

While the complete details of the evaluation will not be repeated here due to space limitations, student responses on several individual items are instructive when considered against the goals, objectives (and limitations) of the Science Studio. On the questions that highlight the strengths of the workshop/studio model—"active student learning," "up-to-date teaching technologies," "effective interactions amongst students," "opportunities to collect/organize/analyze information," "opportunities to communicate conclusions and ideas," and "assessment of student performance in different ways"— Science Studio ratings were significantly above the VCEPT-wide ratings. In areas such as "critical thinking about current events" and "ethical and social implications in the world," which were not emphasized at NSU, the Studio was not rated as highly as it was on the first set of criteria. However, the Studio still scored substantially higher than the large group averages on these questions. Finally, the questionnaire had three questions targeted at teacher candidates enrolled in VCEPT courses. In the NSU course, ten of seventeen respondents identified themselves as future teachers, while 884 out of the total 2,023 responded to this section across the consortium. A four-point Likert scale was used to categorize student responses to questions on how the course had increased their motivation to try different math/science teaching strategies, increased their understanding of how to use those strategies, and how likely they were to share teaching ideas from the course with classmates in the following year. In the Studio course, 80-90% of the students gave the two most positive responses to these questions, while ~70% did so out of the larger group.

Beyond the Studio

The Science Studio was offered on a regular basis from Fall 1996 semester through Spring 2000. Since then, scheduling difficulties and other course commitments have prevented the author from teaching it. The challenge remains to recruit other faculty members within the department to teach in the Studio and provide them the requisite opportunities to become familiar with this mode of instruction. The technologies and methodologies of the Studio have, however, had a tremendous impact on introductory science laboratories at NSU. Through the efforts of James Toy, a physics instructor who attended numerous AAPT meetings to be trained in the techniques of active engagement laboratories, *all* introductory physics laboratory courses have been redesigned (including the one for physics majors) so that they make extensive use of microcomputer based data acquisition. The course activities are based on the *Tools for Scientific Thinking* curriculum [6,21] adapted for the TeamLabs equipment. The professional development opportunities afforded by workshops at the AAPT bi-annual national meetings are an easy way for other faculty members to become familiar with the instructional approaches of inquiry learning as espoused in the Studio. Half-day and full-day workshops are available at a very reasonable cost for teachers interested in learning from other professionals engaged in various methods of instruction informed by research on student learning. The author will continue his efforts to encourage other colleagues to take advantage of these opportunities.

Conclusion

The Science Studio course at Norfolk State University has created an inquiry-based, technology-rich learning environment for non-science majors enrolled in an introductory physical science course. The course model combines traditional lecture and laboratory sections and emphasizes active student learning and opportunities for students working in groups to design experiments, gather data, analyze it and communicate their results to their peers. Evaluations indicate that the Science Studio has been successful in reaching many of its goals. The Studio model has potential to be more effective than lecture in changing students' views about science and its personal relevance. Aspects of the studio model, such as the use of MBL, have been adopted widely in introductory physics laboratories at Norfolk State University. An important goal for the future will be to train additional faculty members in active learning methodologies and the technologies that support workshop/studio instruction to sustain this instructional model [22].

Acknowledgments

The author wishes to thank Larry Mattix, Heidi Ries, James Toy, Phillip McNeil (Norfolk State University), David Jackson and Priscilla Laws (Dickinson College), and Dean Zollman (Kansas State University) for their support in the completion of this project. This work was partially supported under a National Science Foundation Instrumentation and Laboratory Improvement grant DUE 96-53833, by NASA Cooperative Agreement NCC-1-200 and by VCEPT. ■

References

[1] L. C. McDermott, "Millikan Lecture 1990: What We Teach and What is Learned — Closing the Gap," *American Journal of Physics*, **59** (1991) 301-315.

[2] J. M. Wilson and E. F. Redish, "Using Computers in Teaching Physics," *Physics Today*, **42**(34) (1989).

[3] P. Laws, "Calculus-Based Physics without Lectures," *Physics Today*, **44**(12) (1991) 24-31.

[4] S. Raj Chaudhury, "Using Microcomputer Based Laboratories (MBL) to Enhance Student Learning," *Proceedings of the 13th National Educator's Workshop: Update 98*, Brookhaven National Labs, 1998.

[5] E. F. Redish, J. M. Saul, and R. N. Steinberg, "On the Effectiveness of Active-Engagement Microcomputer-Based Laboratories," *American Journal of Physics*, **65** (1997) 45-54.

[6] R.K. Thornton and D. R. Sokoloff, "Learning Motion Concepts using Real-Time MBL Tools," *American Journal of Physics*, **58** (1990) 858-867.

[7] R. J. Beichner, "The Impact of Video Motion Analysis on Kinematics Graph Interpretation Skills," *American Journal of Physics*, **64** (1996) 1272-1277.

[8] I. Halloun, "Views About Science and Physics Achievement: The VASS story," *AIP Conference Proceedings*, **399** (1997) 605-613.

[9] L.C. McDermott, *Physics By Inquiry*, John Wiley and Sons, New York, 1996.

[10] *Powerful Ideas in Physical Science*, American Association of Physics Teachers, College Park, MD, 1996.

[11] D. Jackson and P. Laws, *Workshop Physical Science*, Dickinson College, PA, 1995.

[12] S. Raj Chaudhury and Dean Zollman, "Image Processing Enhances the Value of Digital Video in Physics Instruction," *Computers in Physics*, **8**(5) (1994) 518-523.

[13] *VideoPoint 2.0*, Lenox Softworks, MA, Internet: http://www.videopoint.com/

[14] *Welcome to the Planets*, NASA Educational CD-ROM, Office of Space Science, NASA, 1995.

[15] *A Private Universe* [VIDEOTAPE], Annenberg/CPB, 1992.

[16] S. Raj Chaudhury, "The Science Studio — An Integrated Approach to Physical Science," Paper presented at AAPT National Meeting, San Antonio, TX, 1999.

[17] *Seasons*, Riverside Scientific, St. Paul, MN, Internet: http://www.riversci.com/

[18] *WorldWatcher*, Northwestern Univ., Evanston, IL, Internet: http://www.worldwatcher.nwu.edu/

[19] S. Raj Chaudhury, "Student Attitudes in an Introductory Physical Science Course," Paper presented at the AAPT National Meeting, Denver, CO, 1997.

[20] G. Bass, "Evaluating Reform Teaching in College Courses—Action Evaluation is Action Research," *The Journal of Mathematics and Science: Collaborative Explorations*, **5** (2002).

[21] *Personal Science Laboratory*, TeamLabs, Boulder, CO, Internet: http://www.teamlabs.com/

[22] S. Raj Chaudhury, W. J. Rodriguez, and G. Golembiewski, "Diversifying Physics Teacher Education for the Next Decade," *Proceedings of GIREP 2000 Conference, Barcelona,* Elsevier Press, 2000.

REVISION OF A NON-EUCLIDEAN GEOMETRY COURSE BASED ON THE VAN HIELE MODEL OF THE DEVELOPMENT OF GEOMETRIC THOUGHT

M. P. SHECKELS
Depts. of Education and Mathematics, Mary Washington College
Fredericksburg, VA 22401

Abstract

This paper describes the revision of a course in non-Euclidean geometry to incorporate active student learning. The design of the course and the sequence of lessons were based on the van Hiele model of the development of geometric thought.

Introduction

The nature of high school geometry courses has changed over the years, with some high schools adopting a mixture of both formal and informal approaches to geometry where formal proof is also combined with visualization, problem solving, and applications [1]. Some high schools also offer courses integrating both algebra and geometry. Consequently, students enter college with a variety of geometric knowledge and prospective teachers must be prepared to teach a variety of geometry courses.

At Mary Washington College (MWC), the students who are certifying to teach mathematics in grades 6-12 must complete a major in mathematics. While they are very strong students, the prospective secondary teachers at MWC have indicated that they do not feel as well prepared to teach geometry as other topics in mathematics.

This article describes the revision of a course in non-Euclidean geometry at MWC based on the recommendations from the *Principles and Standards for School Mathematics* [2], the *Professional Standards for Teaching Mathematics* [3], *Moving Beyond Myths: Revitalizing Undergraduate Education* [4], and *Educating Teachers of Science, Mathematics and Technology: New Practices for the New Millennium* [5]. The design of the course was also based on the van Hiele model for the development of geometric thought.

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 25 - 36

Need to Offer a Geometry Course

The non-Euclidean geometry course was designed in the mid-1980s as a 300-level mathematics course for mathematics majors, and it has always been recommended for those students who plan to teach mathematics in high school. I taught this course several times. However, due to a variety of circumstances, primarily difficulties with staffing, the course had not been taught for ten years. Both the mathematics and education departments saw the need to offer a geometry course again on a regular basis. I asked to teach the course and it was scheduled to be offered in the Spring 2002 semester.

Design of the Course

During the summer of 2001, I received support from the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) to redesign the geometry course. The course would continue to be for mathematics majors and recommended for those who plan to teach. I had two basic considerations as I thought about revising the course: what content should I include, and what instructional strategies should I use? In considering the content, I questioned the topics that future teachers need to know in order to teach geometry in middle and high school, the students' prior knowledge of geometry, and how I should balance depth and breadth of coverage. Therefore, I first reviewed the Virginia Standards of Learning for geometry in grades 6-12 [6], the NCTM Standards [2], and various college geometry textbooks.

After reviewing these materials and seeing the scope of knowledge recommended for teachers, I questioned whether or not keeping the focus on non-Euclidean geometry was appropriate for the course, or whether the course should include a more substantial review of Euclidean geometry and more breadth of geometric topics. What was the best kind of course for these students to take to prepare them to teach geometry? It appeared that there would be several options for such a course. A college geometry course could focus more or less on an axiomatic development of geometry. It may or may not include topics, such as transformations, vectors, both 2-and 3-dimensional shapes, projective geometry, and non-Euclidean geometry.

Recently, there have been negative commentaries that the curriculum in the United States is a mile wide and an inch thick. Many reports and articles have called for teachers to develop a deep understanding of the subjects they will teach [1,5,7,8]. *The Mathematical Education of Teachers* states, "A major goal of a collegiate geometry course should be to deepen prospective teachers' understanding of standard Euclidean theorems and principles and their skill in use of axiom-based reasoning." [1] The report goes on to say, however, that prospective teachers should also be acquainted with other aspects of geometry and includes as examples, the geometry of the sphere, conic sections, artistic notions of perspective, Platonic solids, tilings, fractals, and applications such as computer graphics and robotics. However, the report cautions that, "Fitting all of those topics into one college geometry course that also gives an in-depth axiomatic development of Euclidean geometry runs a clear risk of covering ground without developing depth of understanding...it seems promising to survey some topics quickly and then treat a selected few in depth."

I finally decided to keep the focus of this course on non-Euclidean geometry and also try to weave in some of the other topics with which teachers must be familiar. There were several reasons why I decided to keep the focus on non-Euclidean geometry and, after having taught the course, I am very happy that I chose to do so. I believe that the design of a geometry course should be guided by the nature and level of the course and the backgrounds of students who will be taking the course. While it is essential that high school teachers have a thorough understanding of Euclidean geometry, since this course was designed for mathematics majors I wanted it to be more than simply a review of their high school geometry course. In developing the axiomatic systems for non-Euclidean geometry, we reviewed postulates and theorems from Euclidean geometry in more depth. Looking at alternate hypotheses and proving theorems that seem to contradict their common sense help students appreciate the importance of axioms and definitions and help them view Euclidean geometry from a different perspective. Another reason to keep the focus on the development of non-Euclidean geometry is that I have found that students enjoy learning about these different kinds of geometry. Many of our mathematics majors take a course in the history of mathematics, where non-Euclidean geometry is discussed briefly. This seems to whet their interest in the subject and they want to learn more. However, in addition to the focus on the axiomatic development of non-Euclidean geometry, I also wove in other topics the students need to be able to teach, such as rigid motions and three-dimensional solids. I felt secure that the students had studied other topics recommended for future teachers, such as coordinate geometry, matrices and graph theory, in other courses.

Course Goals and Topics

After reviewing several textbooks, I decided to adopt the following text: *College Geometry: A Discovery Approach* [9]. We focused on the content of most sections in Chapters 2, 3, 4, and 6. However, I did supplement it with other materials and resources. The goals for the course were the following:

- students will review and extend the concepts and theorems of Euclidean geometry;
- students will develop their abilities to construct logical mathematical proofs in various axiomatic systems;
- students will learn about the historical developments of Euclidean and non-Euclidean geometries;
- students will learn the basic concepts and theorems of hyperbolic (Lobachevskian) and spherical (elliptic, Riemannian) geometries.

The course began with an introduction to axiomatics and proof, then examined the axioms and theorems of absolute geometry (geometry without a parallel postulate), and then focused on the results that follow from the Euclidean parallel postulate, the hyperbolic parallel postulate, and the elliptic parallel postulate.

Pedagogical Considerations

For the past five years, I had been working with other faculty at MWC and other colleges and universities throughout Virginia as part of VCEPT. VCEPT's primary goal was to better prepare future teachers of students in grades K-8 to teach mathematics and science. I had concentrated on strengthening our program for those students who were enrolled in our elementary teacher preparation program and had designed two new courses. In so doing, I had relied upon educational research on learning and teaching, professional standards, and the VCEPT guidelines for course development. Since teachers teach they way they were taught, I tried to model the same recommended teaching strategies that I espoused for elementary mathematics teachers throughout the course. I wanted to apply some of these reform methods of teaching to this geometry course that would be taken by our future secondary mathematics teachers. In general, I wanted this course to be one in which there was a community of learners actively participating in class and working together to maximize their learning. To achieve this result, I relied upon the van Hiele levels of geometric learning and Phases of Learning as a guide in planning the course and the lessons.

van Heile Levels and Phases

Two mathematics teachers from the Netherlands, who were also husband and wife, Pierre van Hiele and Dina van Hiele-Geldof, devised a model of the development of geometric thought in the 1950s. However, their works did not receive substantial interest in the United States until the 1980s when some of their major writings were translated into English. The van Hieles proposed that students progress sequentially through five levels of reasoning. At Level 0 (Visualization), a person recognizes shapes holistically without paying attention to relevant attributes and may actually focus on irrelevant attributes. A person claims a square is a square simply because it looks like a square. If a square is not oriented so that its sides are drawn vertically and horizontally but instead are on a slant, the person may not believe it is a square. At Level 1 (Analysis), the person can focus more analytically on the relevant attributes of a shape, such as the number and properties of sides and angles, and is not distracted by irrelevant attributes. For example, the person will say that a square has four equal sides, or four square corners, and knows that the orientation of the square on the page does not matter. At Level 2 (Informal Deduction), the person develops an understanding of relationships among shapes and can use informal deduction to justify observations and verify properties. For example, the person knows that a square is a kind of rectangle and a rectangle is a type of parallelogram. A person reasoning at Level 3 (Deduction) can write formal proofs of theorems. This is the level at which we hope students in a college preparatory, high school geometry course are functioning. However, many of these students are still at Level 2 or below. The highest level, Level 4 (Rigor), is highly abstract and reserved for serious students who are typically studying geometry at the college level where axioms themselves are studied and different geometric systems can be compared. A course in non-Euclidean geometry would fall, at least partially, in this last category [10,11].

The van Hieles asserted that students progress through these levels sequentially without skipping a level. A student's progress depends on the content and kind of instruction he or she receives rather than on age. If there is a mismatch between the level of instruction and the student's level of thought, learning may not occur. In order to facilitate a student's progress within a particular level, the van Hieles proposed that instruction be developed according to five sequential Phases of Learning. The initial phase, Phase 1, is Inquiry/Information where the teacher and students begin to discuss the topics so that the teacher can learn what prior knowledge the students have and the students learn what they will be studying. In Phase 2, Directed Orientation, the students explore the topics through the use of materials and structured activities. Phase 3 is Explication where students discuss what they have observed and exchange ideas. Phase 4 is Free Orientation where students work on more complex tasks. These tasks may be open-ended, involve multiple steps, and have a variety of solution methods. In working on these tasks, students may become aware of connections and relationships among the topics and objects they are studying. The final phase, Phase 5, is Integration where students review, summarize, and synthesize what they have learned. When the students have progressed through Phase 5, they should be ready to advance to the next level of geometric thought [10,11].

In designing the course in non-Euclidean geometry, I kept the van Heile levels in mind in two different ways. First, I wanted this course to have the students reason very abstractly, at Level 4. However, I also wanted to make sure that all of the students were ready for that level of abstract reasoning, so I knew that I might need to treat topics at a lower level first. I also wanted to give the students examples of learning at these lower levels in order to prepare them for teaching geometry in middle and high schools.

For each topic that we discussed, I tried to follow the van Hiele Phases of Learning in addition to considering the levels of geometric thought. When working in the lower levels, we progressed more rapidly through the phases; when we dealt with material at the higher levels, we progressed more slowly. In Phase 1, Inquiry/Information, I introduced the topic and helped the students recall their prior learning through questions, discussions, and occasional worksheets, and tried to motivate their interest. In addition to being a review for the students and orienting them to what we would be learning, this knowledge of their background helped me better plan future lessons. In Phase 2, Directed Orientation, I usually gave the students a problem to solve or a fairly structured activity to guide their learning of the content. I looked for worthwhile mathematical tasks that students could work on individually or together that would present them with the concepts we would be studying. Often, this involved drawings or manipulative materials. The textbook had special small units in many sections entitled, "Moments for Discovery" that were often appropriate for this Phase 2. In addition to these, I used problems from the text and other resources. The students also worked on constructions (such as orthogonal circles in a model for hyperbolic geometry) and guided "mini proofs" that could be combined later.

The students in this class were always anxious to move to Phase 3, Explication, so they could share what they had learned from their activities in Phase 2 or ask for clarification on problems they were having. When students asked questions, I tried very hard to turn the question to other members of the class, rather than answering it immediately myself. This promoted good discussion and after a while, the students naturally asked questions to one another and responded. It was a true pleasure to hear all these mathematical discussions taking place in class. For Phase 4, students worked on the more difficult problems or wrote proofs. While there was some collaboration at this phase, I encouraged students to first work individually, perhaps as part of their homework assignment, and then share their results and help one another with problems. Before moving on to the next chapter, or even the next section in the textbook, I conducted a review primarily by asking questions and sometimes making lists to help the students consolidate their learning, clarify any misconceptions, and fill in any gaps in their understanding. These reviews were extremely important, especially as the course material got more involved and abstract. On the last day of class, the students themselves organized and guided a review session to prepare for the final examination.

The following is an example of how we moved through the Phases of Learning in studying about parallel projections. In Phase 1, I questioned the students on what they remembered about similar triangles and what they had learned in their other courses about mappings. For Phase 2, I asked each student to take out a lined piece of notebook paper and I gave each student a blank, 4x6-inch index card. I challenged the students to divide the long side of the index card into five congruent sections using only the lines on the paper. After a few minutes, they excitedly discovered that if you slant the index card so that one corner touches a line on the paper and the corner on the other end of the long side touches the fifth line down from the first line, then the remaining lines divide the index card into five congruent sections. This activity and the discussion that followed in Phase 3 then led to proving the "Side-Splitting Theorem" and homework problems in Phase 4. Reviewing the concept in Phase 5 was done at the end of the chapter.

Using these Phases of Learning was an excellent way to help the students progress through their geometric learning at an appropriate pace in which they were challenged, but there were no gaps in learning. The students greatly enjoyed working with materials, solving problems, and participating in class discussions. While they sometimes struggled with writing the proofs individually, they helped one another and would often remind each other of the activities we had done that related to the theorems to get a better understanding of the concepts involved. They greatly appreciated taking a step to the side occasionally for the reviews, during which I could almost see the puzzle pieces fitting together in their brains. During one class when I was running short on time, I abandoned progressing through the phases and simply slapped a proof on the board. The students clearly did not like this approach. One of the best students, even though she understood each step in the proof, proclaimed, "I don't believe it." She and the others expected to understand what they were proving, to clearly see it, and have it make sense.

Using the van Hiele model, I found that when students worked at the higher more abstract levels of geometry, writing proofs at level 3, and especially in learning about the non-Euclidean geometries at level 4, they were well prepared to do so, having had a solid foundation at the more concrete lower levels. They were able to understand and write proofs in both Euclidean and non-Euclidean geometries.

Examples of Course Activities

I have described below some particular lessons and activities in the course.

History of Non-Euclidean Geometry — Students find the history of how non-Euclidean geometry developed to be very interesting. Our textbook discussed some of the mathematicians involved and how several had tried to prove the Euclidean parallel postulate. However, I thought a more thorough treatment of the historical developments and a deeper look into some of the mathematicians involved would bring the subject to life. Nevertheless, I did not want to resort just to lecturing on the topic. So, several weeks before we started working with the non-Euclidean geometries in depth, I composed a list of ten mathematicians who had been instrumental in the development of non-Euclidean geometry. These were Euclid, Saccheri, Lambert, Lobachevsky, Wolfgang (Farkas) Bolyai, Janos Bolyai, Gauss, Legendre, Riemann, and Beltrami. There were ten students in the class and I allowed the students to pick which mathematician they would like to portray. They then were to research the lives and work of these mathematicians and present the information to the class as if they themselves were the actual people. The role-playing was presented in approximate chronological order, starting with Euclid. Most of the students assumed what they thought would be the personal demeanor of their character. Students made reference to each others' characters personally during their presentations, such as telling Euclid he shouldn't have assumed his fifth postulate and finding flaws in each others' work. Gauss, in particular, took a lot of abuse. The students thoroughly enjoyed this drama, and did a wonderful job in portraying their geometers. Throughout the rest of the course, I would ask a person who played a particular geometer to contribute when introducing a topic or answering a question pertaining to his work. For example, when a question arose about a Saccheri quadrilateral, instead of answering it myself, I referred it to the student who portrayed Saccheri. Likewise, I heard students asking each other questions that their mathematician should be able to answer. The student who played Gauss was so impressed with his initial research that he continued to read more about Gauss, and stopped by my office several times to discuss what he had learned. On the final examination, there were twenty fill-in-the-blank questions on the development of non-Euclidean geometry and the roles of the various mathematicians. Although it had been over a month since we had had the dramatic portrayal of these geometers, the students all remembered the information very well, with most students answering all the questions correctly. In their comments on the course evaluations, students indicated that they thought doing this role-playing was an excellent way to learn about the mathematicians and the development of the field.

Tessellations — In designing the course, I wanted to include some alternate forms of assessment, in addition to the three tests, and show some connections between mathematics and other fields. I also wanted to quickly review the rigid motions of reflection, rotation, and translation in the course, since the students would have to teach these in middle or high school. Therefore, I assigned a project where the students were to design a tessellation through using rotations and translations, and then present it to the class. Going through the Phases of Learning, we first spent a few minutes reviewing rigid motions. Second, we experimented with pattern blocks and sets of plastic polygons to discover the types of polygons that would tile the plane. Then, we discussed regular polygons and angle sums and why certain polygons would tile and others would not. Next, we looked at various works of Escher and learned how to make a "unit cell" by starting with a polygon that would tile, and then cutting a piece from one side and rotating or translating the cut-out piece to produce a unit cell that would tile the plane. For Phase 4, the students created their own beautiful tessellations. For Phase 5, we reviewed the concepts when the students described how they created it to the class. Afterward, we posted the tessellations on the departmental bulletin board. Several students said this would be a project they would use when they teach.

Spherical Geometry — After discussing hyperbolic non-Euclidean geometry for several weeks, I wanted to spend some time on spherical geometry. Initially, we briefly discussed how in this geometry there were no parallel lines, and I drew spheres and circles on the board to try to represent this model. However, since it was in 3-dimensions, it was more difficult to visualize. I had ordered several sets of the Lenart Sphere. Each set consisted of a plastic sphere, three hemispherical acetate sheets, erasable pens for the acetate sheets, a spherical compass, and a spherical protractor. Each student had his/her own set. After identifying what all the components were, I led the class through a guided discovery lesson based on the materials that had come with the instructor's guide. For example, students drew and constructed great circle "lines" on the sphere to see that two of these lines could never be parallel. Students also drew spherical triangles and measured the angles. After comparing answers and some discussion, the students decided that the sum of the angles of these triangles would be between 180 and 540 degrees. The students thoroughly enjoyed working with these physical models and several stated that they would certainly not have been able to understand the concepts without them.

Course Outcomes

Naturally, I will make some revisions when I teach the course again; however, all evidence indicates that the course was a success. While I admit it took work to develop each day's lesson, it was definitely worth the time I spent to try to involve the students actively in their learning. I thoroughly enjoyed teaching the course, much more so than I had when I taught it before, and it was obvious that the students also enjoyed the course very much. Most importantly, the students did very well learning the material in the course. We spent more time in class progressing through the Phases of Learning, using materials and in discussions, and less time on writing proofs than we had when I taught the course before. Nevertheless, the students were equally if not better able to write the proofs of propositions in non-Euclidean geometry that were on the final examination.

On the final course evaluation, the overall rating for this class was 4.78 on a five-point scale. This rating and the ratings in all of the six subsections of the evaluation instrument (course organization and planning; communication; faculty/student interaction; assignments, tests, and grading; and, student effort and involvement) were higher than the corresponding mean ratings for the MWC upper level mathematics courses, the MWC upper level courses, and the mean for four-year institutions provided by the evaluation company. In fact, the ratings on four of the six subsections ranked above the 90th percentile of all the scores for the four-year institutions.

Every student wrote positive comments about the course. One student commented, "I thought this course was fantastic and so much fun. I personally loved it!!!" Another student wrote, "I truly enjoyed this class. My interest in geometry grew tremendously. I enjoyed discovering, proving, and constructing things on my own." Another asked, "When will we be able to take the second half of *Non-Euclidean Geometry*?" Several of the students remarked that not only had they learned geometry, but also how to teach it. One student told me that she hopes she enjoys teaching as much as I do.

On one of the last days of the class, one student asked the others if they remembered a skit at their freshman orientation where students were depicted signing up for a course in non-Euclidean geometry, and it was portrayed as being the most intimidating and incomprehensible course that was offered at MWC. Several chuckled and said that they did indeed remember the skit. Then they commented, much relieved, "And it was not like that at all." ■

References

[1] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2001.

[2] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[3] *Professional Standards for Teaching Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1991.

[4] *Moving Beyond Myths: Revitalizing Undergraduate Education*, National Research Council, Washington, DC, 1991.

[5] *Educating Teachers of Science, Mathematics and Technology: New Practices for the New Millennium*, National Research Council, Washington DC, 2001.

[6] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[7] L. Ma, *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States,* Lawrence Erlbaum Associates, Mahwah, NJ, 1999.

[8] L. S. Shulman, "Those Who Understand: Knowledge Growth in Teaching," *Educational Researcher* **15**(2) (1986) 4-14.

[9] D. Kay, *College Geometry: A Discovery Approach,* Addison Wesley Longman, Inc., Boston, MA, 2000.

[10] *Learning and Teaching Geometry, K-12,* National Council of Teachers of Mathematics, Reston, VA, 1987.

[11] G. Musser, W. Burger, and B. Peterson, *Mathematics for Elementary Teachers,* John Wiley and Sons, Inc., New York, NY, 2001.

THINKING ABOUT GEOMETRY: LAYING A FOUNDATION FOR FUTURE K-8 TEACHERS

L.D. PITT
Depts. of Mathematics and Statistics, University of Virginia
Charlottesville, VA

Introduction

In 1997, the University of Virginia (UVA) joined the NSF-funded Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) and led the Collaborative's effort in thinking about geometry courses that would be most appropriate for future K-8 teachers. Working with other VCEPT institutions, we centered our discussion on two basic questions: What parts of elementary geometry are important for K-8 students and why are they important? What types of experiences will future teachers need in preparation to teach K-8 geometry? In this article, I will discuss a geometry course for future K-8 teachers that grew out of this effort. Similar courses were implemented at other VCEPT institutions.

The philosophy of our course is grounded in our conclusion that elementary and middle school geometry is learned primarily by doing and questioning. Our course turns on exploratory hands-on activities; building, cutting, and looking for patterns and structures; activities designed to help the student develop spatial sense, an understanding of spatial structures, and visualization skills. The course's content and format, together with several illustrations of the activities, are discussed here. I have tried to present the material and my views with a minimum of educational terminology, and in a manner that is accessible to all interested parties including, especially, other college mathematics faculty. The discussion begins with a personal look at some specifics separating the history and content of K-8 geometry from the primary strand, arithmetic, in the traditional school mathematics curriculum.

Kenneth Hoffman, after spending years representing mathematics and mathematics education in Washington D.C., often illustrated an essential difference between science education reform and mathematics education reform by drawing attention to the fact that educational change is most difficult when the subject of reform is familiar to a wide audience. He observed that, until recently in the United States, almost all adults had experienced a highly standardized

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 37 - 49

K-8 mathematics education focused on arithmetic skills. In contrast, few adults studied substantial amounts of science in the elementary grades. The omission of science is now recognized as having been a mistake, and as a nation we are quite open to innovative teaching and reform in our science classrooms. But, we all studied mathematics and most of us believe that we know what mathematics is and how it should be taught. We tend to be very suspicious of a change that leads toward mathematics instruction philosophically different from that which we experienced in our childhoods. We react in this way in spite of overwhelming evidence that the old methods of mathematics instruction only succeeded with a small minority of students—and they did not succeed with many who oppose reform in mathematics.

The history of K-8 geometry instruction is closer to that of science than to arithmetic. While the subject of geometry is old, except for a few area and perimeter formulas and some instruction on the use of rulers, geometry and measurement were always neglected in the elementary and middle school curricula. As with science, educators generally view this neglect as having been a mistake and an increased emphasis is being placed on geometry. We are, however, starting with very little history in geometry. In K-8 geometry, there are no hard American beliefs or traditions based on previous experiences. At this moment, we are quite free to think through geometry instruction fresh from the ground up. Our generation of mathematics teachers and educators is, in essence, inventing a new subject, or at least a new curriculum. Now and perhaps for a few years while a new norm is precipitating out, we have great latitude to consider geometry's content, rationale, and pedagogy. This is an unusual opportunity that can benefit future generations of students.

As we consider geometry and teachers' needs, two recent documents from the professional communities, the National Council of Teachers of Mathematics (NCTM) 2000 *Principles and Standards* [1] and *The Mathematical Education of Teachers* [2], are especially important. They lay solid groundwork, but they are not complete. Serviceable answers to questions of this type never are. Local circumstances and resources play a large part in determining what is possible. Answers also depend on our changing understanding of the roles of geometry in the broader world, and depend on our knowledge of the concepts children must assemble to construct geometric skills and our understanding of the ways children learn geometry. Regrettably, this knowledge is rarely found where it is needed; especially in college mathematics departments and even among mathematics educators. Over the last five years, I worked to develop my own thinking on these topics. This article and the course it describes provide a snapshot of my present understanding. The next section contains a few personal thoughts on geometry and observations on how we learn it.

History of Geometry and Geometry Education

Basic geometry and measurement concern our physical world. The roots of the Greek word "geometry" translate as measurement of the earth: *geo* means earth or world, and *metry* means to measure. This aspect of geometry predates and underlies the more abstract subject of Euclidean geometry. It is, or should be, the essential core of school geometry. The ancient Greeks credited the Egyptians with the origins of the subject. The Nile's yearly floods created an annual need to survey the land; and, Egypt also had a large government whose construction projects, ranging from irrigation canals, temples, and monuments, to office buildings, generated other needs for applied geometry. The early Egyptian geometer's tools included measuring sticks or granite "cubit rods" with chiseled "digit" marks, knotted ropes for measuring longer distances, plumb bobs for establishing vertical directions, squares for constructing perpendicular lines, and compasses for duplicating lengths and constructing circles. Dilke's *Reading the Past* contains an attractive account of this, together with photographs of ancient measuring implements [3].

Egyptian geometers had a strong working knowledge of area and volume calculations and were competent with much of the geometry used today by surveyors, architects, and carpenters. These practical applications gave rise to the development of geometric concepts that are the essential prerequisites for abstract Euclidean geometry. The hands-on work of developing these worldly concepts in children remains the prerequisite for success in their later study of geometry; prerequisites that have been largely ignored for centuries in our schools. How this happened appears largely to be an historical accident.

Geometry entered Europe's historical consciousness after first being filtered through two of history's most influential, successful, and sophisticated philosophical schools: Plato's *Academy* in Athens and the *Library* in Alexandria. These schools were the world's great centers of learning and research. They were unlike today's schools, but it is quite reasonable to view them as ancient analogues of today's research universities. Euclid worked at the *Library* in Alexandria and wrote his great text *The Elements* at the end of the fourth century B.C. It was a scholar's book; an advanced text written for scholars. *The Elements* became Europe's only geometry text for the next two millennia. But a great historical irony occurred as Europe emerged from the Dark Ages and Euclid was rediscovered. *The Elements* became the only source on the subject and all prerequisites disappeared from sight. History's great graduate text became our schoolchildren's text, and the high school geometry book that I used in 1955 was only slightly altered from the first volume of today's standard edition of Euclid [4].

Learning Geometry

The use of Euclid maintained the rigor of geometry, but the origins of the subject with its rich applications to the physical world and all pedagogical considerations disappeared from the schools. The face of geometry became abstract, advanced, and removed from daily life. Children suffered and until very recently, geometry was a subject where only the best and most dedicated students succeeded. Middle school children were not exposed to mathematics that could prepare them for success in high school geometry because we did not recognize that such preparation was necessary or possible. A great gap separated students and the almost sacred text. Only in our times, when research began to illuminate how children learn geometry, did it become possible to glimpse the damage that was being done by traditional geometry instruction [5-7]. Our UVA course attempts to bring the preparation of teachers in line with the type of instruction we now believe is needed for children to learn geometry.

Based on the work of the van Hieles and their successors, we now know that as children and adults learn geometry and measurement, they progress through a developmental sequence in which they piece together their understanding of the elements of geometry: elements like units, dimensions, arrays, angles, area, and congruence. The developmental sequence is largely dependent on the students' experiences; experiences in which they build, measure, and solve problems. Children develop spatial sense and their understanding of geometry by constructing their own (mental) spatial structures that are superimposed on space. All these structures depend on geometric experiences, and the experiences must fit with the students' development. When needed experiences are left out, parts of the developmental conceptual development does not occur. The conceptual gaps become blind spots for students that can remain forever. Typically, these blind spots are not eliminated with formal instruction where students memorize vocabulary, definitions, and theorems, but only with experiences that build the missing concepts and spatial understanding.

It is as if the gaps are missing rungs on a ladder that a student is trying to climb. When too many rungs are missing, the student cannot proceed. This ladder of understanding becomes the true intrinsic prerequisite for success in geometry. This is, in fact, true in a very strong sense.

The subject's logic and language at one level are unintelligible to students at lower levels of development. Using this vocabulary of intrinsic prerequisites, it has been observed that students possessing the prerequisites are typically successful in geometry, and those without the prerequisites typically fail. If our schools have not taught the prerequisites for high school geometry, it is not surprising that few students master the subject. One successful high school teacher of many years' experience recently told me that she has never taught a geometry student that mastered and enjoyed the geometry course in the same manner that these students did with other advanced mathematics courses. Teachers must understand these issues, and they must be able to build activities into their curriculum that allow students to build their own conceptual ladders.

Examples of Missing Rungs

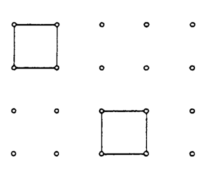
The above remarks are difficult to understand in the abstract without concrete examples. The following examples are taken from my experiences teaching informal geometry to undergraduates at UVA. The examples illustrate both typical activities in the course, and problems that students must cope with when they are missing rungs in their conceptual ladder. The students that I refer to here are all talented and dedicated, and have successfully completed a high school geometry course. Their academic achievements were sufficient to earn admission to an elite, highly selective university, but they often did not understand the simplest geometric concepts: concepts like squares and rectangles. Before I taught the informal geometry course at UVA, neither I nor others in our mathematics department knew these education gaps existed. The examples provide compelling evidence that for many, successful completion of a high school geometry course has been a farcical experience. They have been swindled.

To help students learn of the many conceptual pieces that go into a mature understanding of concepts like volume and area, we present a relatively complete developmental development of area [8]. The missing ingredient in our development is time; in part because of college instructional schedules, and in part because we originally assumed that our students have a solid foundation in school mathematics, and that their primary need is for them to experience how the pieces fit together. The original area sequence included activities where:

- areas of simple, differently shaped regions were compared;
- students were asked to construct a rectangle with the same area as that of an irregularly shaped region;
- students found areas of simple and complex polygons on Geoboards and drawn on square dot paper;
- students dissected and recomposed regions to develop standard area formulas and the Pythagorean Theorem; and,
- students both compared and measured the areas of irregularly shaped regions.

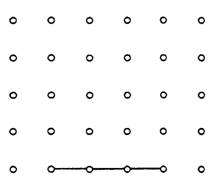
<u>Example One</u> — My first surprise discovery was that many students have never engaged in meaningful activities with squares and rectangles. More precisely, their experiences with geometry were so shallow that they did not lead to a usable understanding of squares and rectangles. These students possessed no precise information about these shapes that can reliably be called upon when measuring or drawing a square or computing its area. Some had never used a ruler.

One particular activity starts with a few line segments drawn on square dot paper. For each given segment, the students are asked to construct a square with the segment as one edge. They are then asked to find the area of the square. The purpose is to develop an understanding of area, but visualization and elementary construction skills are the essential tools. I assumed, without consciously expressing the thought, that all students would be able to see that the dots on the paper outlined small squares,

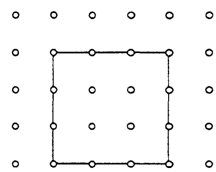


that these squares cover the plane in a regular array, and that the squares could be used as units for measuring area. My assumptions were naïve. Most students owned most of this picture, but their knowledge was not always structured in a usable way, and in some there were very surprising gaps.

When the line segment on the sheet looked like that in figure A, then the students quickly produced the drawing in B.



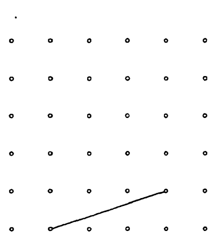
A



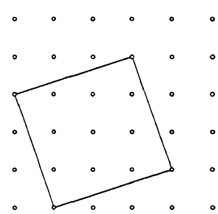
B

In this case, there was a high probability that they would give the correct answer for the area of the square, but a few would consistently count the dots rather than the spaces and reach the conclusion that this is a 4 by 4 square rather than a 3 by 3 square.

The next step raised the level of difficulty more than I imagined. This time there was a segment like that in figure C, for which I expected the answer drawn in D.



C

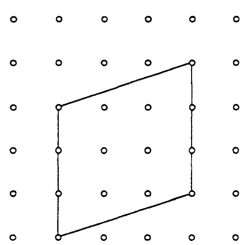


D

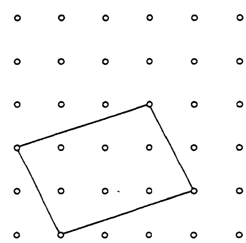
I anticipated that the students' responses would be governed by knowledge that squares have equal angles and equal sides. If they knew this, then even if they could not see the pattern for constructing the square, I felt that trial and error would lead to the correct solution. Eventually the pattern, "*When the bottom edge goes over three spaces and up one space, then the right hand side edge will go up three spaces and over one*" would emerge. In any case, since algebra students have been taught the rule for the slopes of perpendicular lines, they could resort to using this fact as a last resort. I thought they would be able to use this to find the square algebraically, even if they did not see the geometric pattern. Finally, I expected that the most visually talented students would see the square as having been rotated slightly about its center, and for them the rule should follow. This was not the case. Not at all.

Typical students would have some initial trouble, but would discover how to construct the triangle in a few minutes. They used the anticipated trial and error approach with little or no analysis, but they became visually adept at finding the square's missing sides. In discussions, none mentioned perpendicular lines or slopes. One highly exceptional student mentioned the rotated square idea.

The real surprise came with students, often as many as 15% at UVA, who drew figures like those in E and F.



E

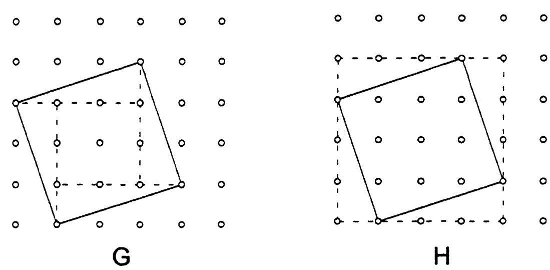


F

These students turned out to be members of a large segment in our society for whom the sentence, "This is a square," means approximately that, "This figure looks much like other figures that we call squares." For these students, squares do not have sharp mathematical definitions and properties, but "square" is a fuzzy concept. Squares are "squarish" with more or less equal angles and more or less equal sides that are more or less straight. Some adult students do not recognize squares when the bases are not aligned with the edges of the paper. The students had passed geometry courses, but there was a giant gap between what they were thinking and what we thought we were teaching! For them, after years of instruction, squares had not entered the domain of precise mathematical argument.

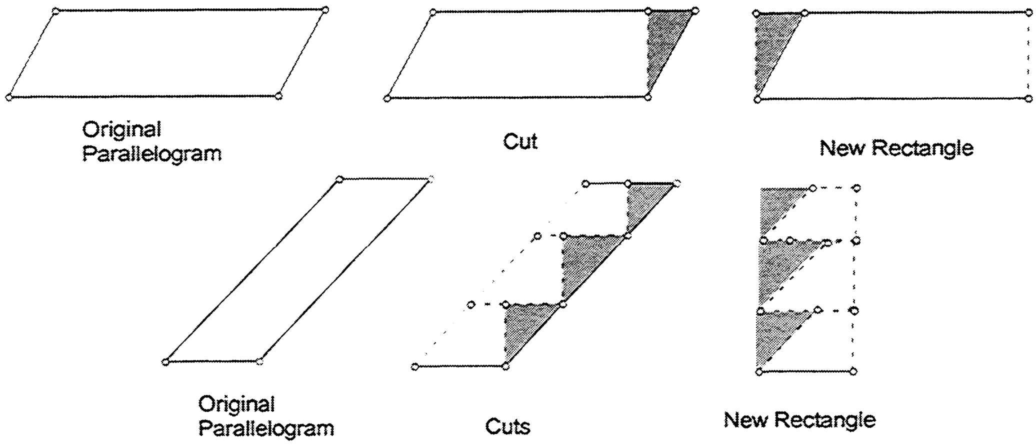
As the course progressed, observation showed that these individuals were not lacking mathematical talent, but they lacked the habits of precise mathematical thought and the rich experiences from informal geometry that build precise geometric concepts. In personal interviews, some students stated they had never built things with blocks or tiles, or hammer and nails. Others had never used a ruler or a protractor. They were truly geometrically deprived, and the other students, the successful students, were not far ahead! They had not had experiences that taught things like the practical importance of right angles and perpendicular lines. Without this background, no understanding of right angles and the squares of mathematics was possible beyond that of an abstract definition to try memorizing for the test. In fact, they did not understand that the mathematics they had been taught depended on the properties of squares. In my square problem, they looked for the square that I desired, and when it proved to be difficult to find, they settled for something that looked sort of like a square. They never saw a reason why it might matter.

Other gaps were disclosed in the students' area calculations. By this time, the students had repeated experiences with dissection problems, and most found the correct area by using one of the dissections indicated in figures G and H.

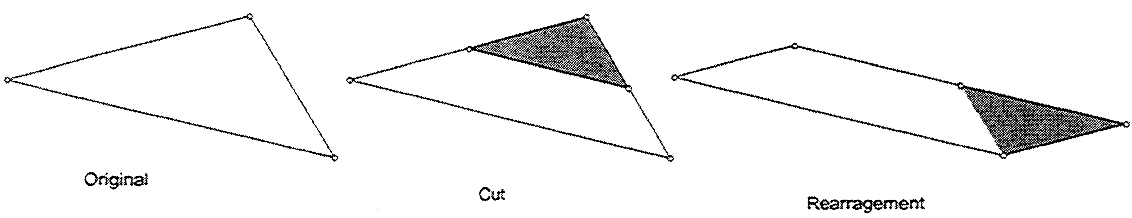


In figure G, the area is shown as the area of the small inscribed square of area 4 squares together with the areas of 4 triangles, each of area 3/2 squares, while H shows the area to be from the large circumscribed square of area 16 squares by removing 4 triangles of area 3/2 squares each. These students basically understood the structure of the grid paper, but those that did not produced a variety of mistakes, including several in which the area was reported to be 9 squares because the *length* of the segment was perceived to be 3 units.

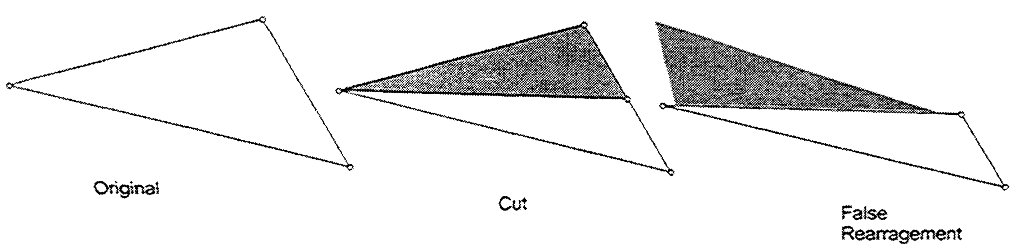
Example Two — A second set of area dissection problems asked students to cut simple regions into pieces and reassemble them to make other simple shapes. For example, making a rectangle out of a parallelogram leads to the area formula for a parallelogram. Here are two appropriate cuts for this purpose.



A similar, but slightly more advanced problem is to cut a triangle into two pieces and reassemble it into a parallelogram. The standard cut and rearrangement for this is illustrated in the next three figures. Midpoints of two opposite sides are joined and the tip cut off and joined to either end of the resulting trapezoid.

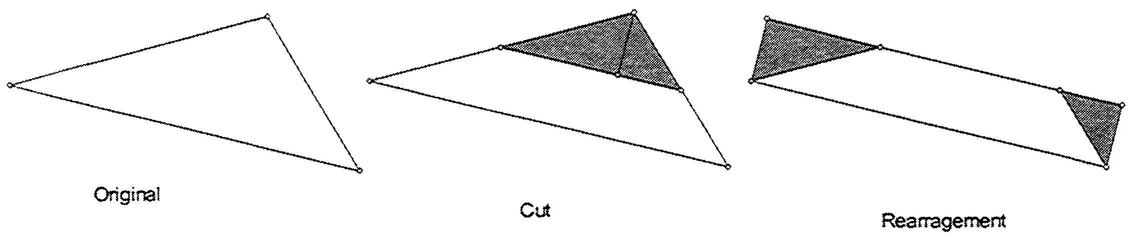


Students, and the reader, are asked to justify that the resulting figure is a parallelogram. This problem also has its own standard false solution:



The point to observe in this figure is that, while the resulting figure resembles a parallelogram, upon close examination it is clearly not one. The example again exhibits that students who have not had sufficient experience to construct an appropriate mathematical understanding of a parallelogram, are ready to accept as a solution anything that looks close.

Example Three — Finally, I will mention the problem of cutting a triangle to make a rectangle. Here is one solution.



In this problem, I have observed UVA undergraduates using a completely non-mathematical approach by repeatedly cutting off bits and pieces until something roughly rectangular is achieved. In the most extreme case of this that I have seen, the figure that was submitted as a rectangle had, in fact, nine sides.

Lessons Learned

Geometry's roots are in the physical world, and for most students its importance must be understood in these terms. Elementary geometry is the focus of our work when we are learning to make sense out of the physical/geometric world of shapes, solids, and space. These activities are dominated by a few fundamental ideas and the relationships between them: length, area, volume, angle, congruence, similarity, and symmetry. The importance of an informal mastery of these topics can hardly be overemphasized. They give the student a set of powerful skills and tools that are referred to as spatial sense, but might also be termed the geometer's eye. With them, students see spatial structures that are invisible to those without these skills. These skills are of great utility in many technical occupations ranging from heating technician to engineering. The same skills are important to artists, movie animating technicians, craftsmen, and furniture movers. They are also the foundation for the insights that geometry students need to understand definitions, theorems, and proofs.

Through the observations discussed in the last section and the research on how children learn geometry, it becomes clear that most of the future teachers that I have taught will not be prepared to teach their students to see spatial structures and relationships without considerable work. For them to become effective, a special geometry course is needed that will teach them the content, but more importantly, the course must have the power to transform future teachers into mathematical thinkers. Within their minds, the topics of elementary geometry, such as squares and area, need to be transformed into subjects where mathematical precision and analysis are applicable.

With a coherent set of geometric activities, future teachers can develop their own geometric concepts. But teachers require more than a superficial understanding. Their experiences must prepare them to create rich, geometrical classroom environments that can serve their students' geometric needs. In earlier times, rural environments and physical activities both at home and in the crafts, provided many children with opportunities to learn basic geometry outside the classroom, but very few children have comparable experiences today. Generally, the needed experience can only be found in the classroom, and for this reason there is a special need for geometry-rich environments in our schools. Geometry is a natural subject to integrate with other parts of the school curriculum, and a geometry course for future teachers must prepare teachers for this task.

Our UVA course is our first attempt to address this issue. The course has been popular with education students. These students learn considerable amounts of informal geometry. Through their experiences, they gain knowledge of the developmental sequence for learning geometry, and the use of hands-on activities with physical objects in geometry instruction. The unanswered question is whether the course is sufficient. The course moves students in the right direction, but does it effectively fill the geometry gaps that our students bring to college? ■

References

[1] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[2] *The Mathematical Education of Teachers*, Conference Board of the Mathematical Sciences, The American Mathematical Society, Providence, RI, 2000.

[3] O.A.W. Dilke, *Reading the Past: Mathematics and Measurement*, University of California Press, Berkeley, CA, 1987.

[4] Euclid, *The Thirteen Books of The Elements*, Translation and commentary by T.L. Heath, Dover Publications, New York, NY, 1956.

[5] M.L. Crowley, "The van Hiele Model of Development of Geometric Thought," in M.M. Lindquist and A. Shute (eds.), *Learning and Teaching Geometry, K-12*, National Council of Teachers of Mathematics, Reston, VA, 1987.

[6] D. Fuys, D. Geddes, and R. Tischler, "The van Hiele Model of Thinking in Geometry Among Adolescents," *Journal for Research in Mathematics Education*, National Council of Teachers of Mathematics, Reston, VA, 1988.

[7] D. van Hiele-Geldof and P.M. van Hiele, *Selected Writings of Dina van Hiele-Geldof and P. M. van Hiele, English Translation*, D. Fuys, D. Geddes, and R. Tischler (eds.), Brooklyn College, Brooklyn, NY, 1984.

[8] L.D. Pitt, M.A. Timmerman, and C.E. Wall, "Geometry for Teachers of the Middle Grades," Dept. of Mathematics notes, University of Virginia, Charlottesville, VA, 1999.

Appendix A
(Syllabus Outline)

- Experiences and learning geometry: the van Hiele model;
- Length: comparisons and measurement;
- Angles: comparisons and measurement;
- Area: comparisons and measurement, explorations; comparisons, dot paper, Geoboards, cutting and recomposing, formulas, informal units, Pythagorean Theorem, similar figures, irregular figures, perimeter and area;
- Volume: comparisons and measurement, explorations; cutting and recomposing, informal units, surface area and volume of familiar solids and irregular solids, similar figures;
- Shapes: sorts, and properties;
- Analysis: angles, and parallel lines;
- Analysis: triangles, decomposing and recomposing, angle sums;
- Analysis: geometry on the surface of a balloon;
- Regular polygons;
- Constructions: with paper folding, with compass and straightedge;
- Symmetries: reflections with paper folding, mirrors, and MIRA's;
- Transformations and symmetries in 2 dimensions;
- Symmetries in 3 dimensions;
- Tessellations.

A MODEL GENERAL EDUCATION SCIENCE COURSE INVOLVING HUMANITIES AND SCIENCES, EDUCATION, AND MEDICAL SCHOOL COLLABORATION

J.P. CHINNICI
Dept. of Biology, Virginia Commonwealth University
Richmond, VA 23284-2012

Abstract

This article described an innovative general education biology course for non-science majors, *BIOL 102-Science of Heredity (SOH)*, stressing active student learning and collaboration [1]. The course has three components. The lecture is taught by J. P. Chinnici and several undergraduate "teacher apprentices"; students receive a classnotes packet, take in-class quizzes, and interact to work on genetic worksheets; incentives include reviewing books, visiting a science museum, and finding albino squirrels. Recitations are taught by graduate students in the Department of Human Genetics; student activities include preparing a family pedigree, writing a term paper, reporting orally and in writing on several media articles they find, and class debates on topics of societal importance. Laboratory exercises include working with "flightless" fruit flies to determine the mode of inheritance of a mutant trait, isolating and analyzing DNA using gel electrophoresis, and a forensics exercise using genetic clues to identify a suspect. Results of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) assessment of the course are given and briefly discussed.

Introduction

I have had a long-term interest in improving the science literacy of college students through increasing the effectiveness of general education science and mathematics courses taught to non-science students [2]. During the mid-1990s, the Virginia Commonwealth University (VCU) College of Humanities and Sciences undertook a major revision of its general education requirements and I played a role in that process [3]. This period coincided with the activities of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) initiative and provided an opportunity for VCEPT to integrate a number of innovative teaching and learning practices into a group of general education science, mathematics, and integrated math-science courses at VCU.

I will describe one of the VCU general education biological science courses developed by VCEPT. In the case of *BIOL 102-Science of Heredity (SOH)*, accommodation of the VCEPT

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 51 - 58

learning objectives into a course with an enrollment of 200 students per semester required the cooperation of three academic units at VCU: The Schools of Medicine and Education, and the College of Humanities and Sciences. The leadership of each of these units was willing to act in unconventional ways to create this course, and in so doing created a synergistic relationship in which all parties (students and the various instructors) have benefited.

VCU *BIOL 102: THE SCIENCE OF HEREDITY (SOH)*

With the virtual completion of the Human Genome Project, genetics continues to increase in importance in modern society. Nevertheless, the subject of genetics has traditionally been considered quite challenging to non-science oriented students at both the high school and the college levels [4-9]. By employing as many tools as possible to encourage active student learning, both individually and cooperatively among students, and focusing on connections of classroom topics and real-world examples, I sought to focus student attention on the benefits of their understanding somewhat difficult topics in order to motivate them to relate those ideas to their individual lives.

In designing the *SOH* course, I sought to include all of the VCEPT general criteria for course development, namely: producing well-informed citizens through a broad-based core of knowledge; fostering active student learning; using modern teaching technologies and methods; stressing connections with related disciplines; fostering intellectual communities among students and instructors; and, assessing student learning in a variety of ways.

Mechanics of the Course

The *SOH* course is divided into three components: class meetings ("lecture") during which the entire class of 200 meets for 75 minutes twice weekly; ten small group meetings of twenty students each for enhancement activities (non-traditional "recitation") which meet once weekly for 50 minutes; and, several laboratory sessions of sixteen students each which meet once weekly for two hours. Students earn four credits for the lecture-recitation, and one credit for the laboratory. Although the laboratory is optional, about 60% of the lecture-recitation students also take the laboratory.

Comments about Lecture

A class syllabus is posted on the VCEPT website [10]. The lecture is a mix of the traditional and the innovative. Students receive a printed packet with reproductions of all the class notes on the first day of class, to encourage active listening during class. While having all the class notes could encourage students to cut class, I offer an incentive to attend: each period, students take an "in-class quiz," consisting of a series of multiple choice questions based on that day's topics, interspersed throughout the class activities. The cumulative average of the in-class quizzes counts the equivalent of a major exam grade. I offer this as a "carrot" for good attendance and no more than 10% of the class is absent on any given day.

One innovation during lecture is the use of "genetic worksheets." Typically, once or twice a week, students are given a one-page, problem-oriented exercise based on a practical application of the concept currently under discussion. Students then work together in many small groups for about five minutes to discuss and solve the worksheet. Then, the class as a whole discusses the worksheet solutions. These discussions are led by a pair of "teacher apprentices" who are former students in the course and who have volunteered to return to be in charge of the worksheets. Typically, the teacher apprentices are to some degree interested in the idea of becoming teachers. We have been paying these students an hourly stipend for their time, but may begin awarding them academic credit in lieu of the stipend.

The teacher apprentices also are actively involved in testing innovative exercises that may enhance student learning. For instance, during the Spring 2002 semester, two apprentices ran several voluntary after-class sessions with students, in which the students played the role of "human chromosomes" and acted out the various stages of mitotic and meiotic cell division. Subsequently, the entire class was given a difficult ten-question, extra-credit test, and the scores of the 39 students who role-played cell division were compared statistically to the 168 students who did not participate in the role-playing. The role-playing students averaged 55.1% correct on the bonus items while the non-role-playing students averaged 47.9% correct. Figure 1 shows the distribution of the percentages of correct answers on the extra-credit questions for these two groups of students. A t-test analysis of the data showed that the performances of the two groups was statistically significant ($t = 4.639$ with 36 degrees of freedom, $P < 0.0001$).

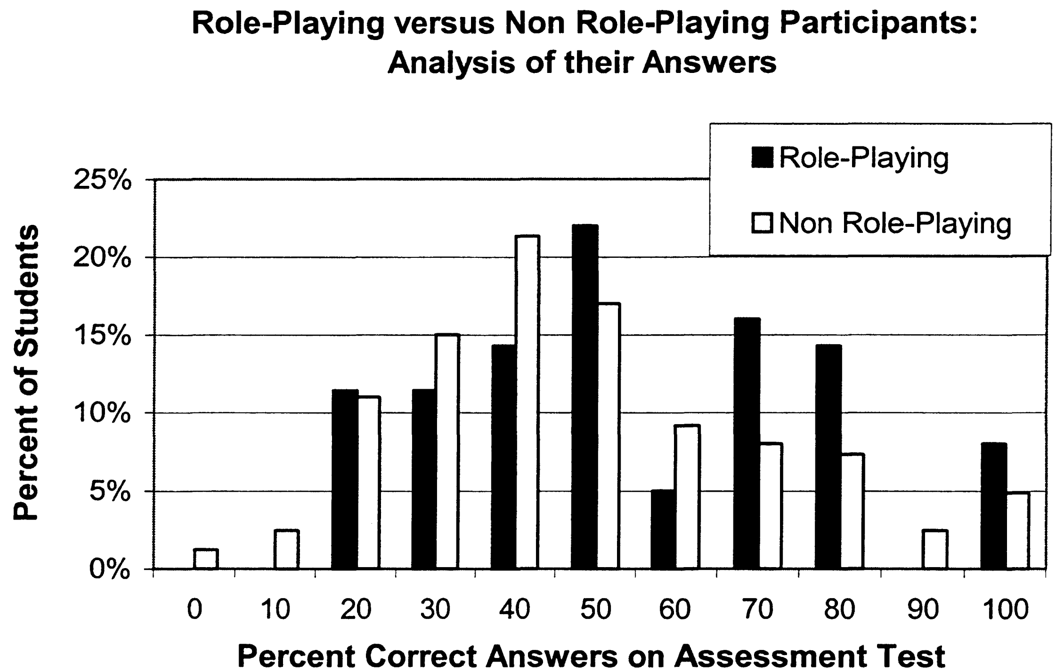


Figure 1. Bar graph showing the percentage of correct answers for ten extra-credit questions asked in *SOH*, comparing the 39 students who role-played mitosis and meiosis with the 168 students who did not.

Many additional incentives are offered throughout the lecture course to help students stay on track. Students may earn extra credit by performing activities that may make them more aware of the intersections of genetics and society. For example, they can find and photograph albino squirrels that live throughout the city, they can visit the Science Museum of Virginia which recently opened a permanent exhibit on DNA and genetics, and they can read popular books with genetics content from my "genetics library" and write reaction reports on their contents. In any given semester, about one-third of the students turn in at least one extra-credit activity.

Recitation

Recitation instructors are graduate students (either Ph.D. seeking students or M.S. in Genetic Counseling students) from the Department of Human Genetics in the VCU School of

Medicine. The first time they teach, these students sign up for a 700-level School of Education Teaching Externship course to earn academic credit for their teaching. The externship consists of weekly meetings with the course director, a recitation class visitation by the course director followed by a meeting to critique the graduate student's performance, and keeping a weekly journal of teaching experiences. If they choose to teach in subsequent semesters, they are paid as adjunct faculty. The graduate students gain valuable teaching experience, typically not available to them elsewhere, and the course benefits from their fairly broad knowledge of genetics. Students in the class find it easy to relate to these young scientists-in-training, which dispels the notion that scientists are somehow "different" or "weird."

Much active student learning occurs in recitation. Rather than just rehash what is covered in lecture, the content of recitation extends lecture concepts and often covers new subjects. For instance, students discuss the overpopulation problem and potential genetic "solutions" including the "one child" policy in China and the eugenics movement. Students also organize themselves into teams to debate the topic of whether genetic testing at the pre-natal, neo-natal, and adult stages should be mandatory for a variety of genetic traits. Students also prepare a detailed family pedigree for one or more traits, and write a term paper on a genetic condition of personal interest. Students are required to scan the print media to find three articles dealing with genetics, write personal reactions or responses to the articles, and chat with their recitation classmates for five minutes about each article. Written student evaluations of recitation are overwhelmingly positive regarding both the graduate instructors and the recitation content [1].

Laboratory

M.S. degree seeking graduate students in the VCU Department of Biology are the lab instructors for *SOH*. The labs take a hands-on approach to working with some aspects of genetic technology. Students isolate DNA from onions, make agarose gels, and run gel electrophoresis on DNA samples from a hypothetical family to determine the genotypes of individual offspring for some genetic condition. Students also participate in a forensic genetics exercise in which they identify a prime suspect based on crime scene information. One innovation in the *SOH* lab is a study using special strains of "flightless" fruit flies to determine the modes of inheritance of a variety of mutant traits. Students work in pairs to identify their "unknown" trait, and then set up three generations of matings to determine whether their trait shows autosomal or X-linked and either dominant or recessive inheritance.

Assessment of the *Science of Heredity*

At the end of the Fall 1999 semester, VCEPT evaluated 36 of the courses in the project, using an evaluation questionnaire filled in by students in the various classes [11]. *SOH* was among the courses evaluated. Table 1 summarizes the results of the evaluation, including data from *SOH* (184 students) and the overall data from the 37 courses (2,045 students).

Table 1
VCEPT Fall 1999 Evaluation Questionnaire Summary

Data for *BIOL 102 Science of Heredity* compared with overall data from 37 courses, including *SOH*. Feedback on course:

Students used these five-point rating scales to describe the presence and value of course characteristics:

A = Systematic use (100% of classes)	A = Very Important
B = Customary use (75%-99% of classes)	B = Important
C = Frequent use (50%-74% of classes)	C = Unimportant
D = Moderate use (25-49% of classes)	D = Detrimental to your learning
E = occasional use (0%-24% of classes)	E = Not Applicable or No Opinion

"To what degree did the classes in this course include"
"To what degree are these course characteristics important in helping you learn in this course?"

VCU *BIOL 102 SOH* Number of Respondents = 182
(37 Courses Overall Number of Respondents = 2045)

	Presence [%]					Value [%]				
	A	B	C	D	E	A	B	C	D	E
Active student learning	32	39	21	4	3	54	40	4	1	3
	(31	35	20	9	5)	(57	33	7	1	2)
Up-to-date teaching technologies	32	40	17	8	3	31	52	14	1	2
	(29	37	18	10	5)	(39	43	15	2	2)
Connections to other related disciplines	23	41	21	10	5	35	48	15	1	1
	(16	33	27	15	9)	(25	52	17	3	4)
Connections to the natural world	46	42	7	2	2	41	45	10	1	3
	(35	30	18	10	8)	(33	44	16	3	4)
Mixture of breadth and depth in coverage	34	48	15	2	1	40	49	8	1	2
	(25	37	25	9	4)	(31	50	12	2	4)
Interesting and intellectually involving concepts	46	40	12	2	1	62	32	5	1	1
	(29	33	23	10	6)	(49	39	8	2	2)
Critical thinking about current events	29	35	24	8	4	33	51	14	1	2
	(14	25	25	18	17)	(23	44	22	4	6)
Practical applications to students' own lives	27	37	25	9	2	37	51	11	1	1
	(20	28	24	17	12)	(36	45	14	3	3)
Effective interactions among students	22	34	24	13	8	20	48	26	2	4
	(22	31	25	13	9)	(32	45	18	3	3)
Opportunities to collect pertinent information	24	35	26	10	5	19	52	22	2	6
	(20	33	27	12	7)	(28	48	18	2	5)
Opportunities to organize information	32	32	23	10	3	26	51	16	1	5
	(24	33	27	11	5)	(30	49	15	2	4)
Opportunities to analyze information	28	46	19	6	2	34	50	12	2	3
	(25	36	26	9	5)	(35	49	11	2	3)

Opportunities to communicate conclusions and ideas	26	33	24	10	7	32	51	12	1	4
	(21	31	27	13	8)	(33	49	12	2	4)
Ethical and social implications in the world	31	31	26	9	2	34	52	10	2	2
	(15	24	27	18	16)	(25	44	20	3	8)
Assessment of student performance in different ways	25	37	24	10	4	41	44	10	1	3
	(22	30	25	14	9)	(41	44	11	2	3)

1. Academic classification at the beginning of the 1999 fall semester [%]
Fresh- 20 (38) Soph- 35 (25) Junior- 27 (17) Senior- 16 (13) Graduate or Unclassified- 0 (5)

32. Do you plan to become (or are currently) certified to teach? [%]
No = 70 (57) Yes, grades K-5 = 15 (18) Yes, grades 6-8 = 1 (3) Yes, grades 9-12 = 3 (5) Undecided = 10 (10)

Students planning to teach use the following four-point scale to respond to these questions
A = Strongly agree B = Agree C = Disagree D = Strongly Disagree

	A	B	C	D
This course experience increased my motivation to try a variety of math/science teaching strategies in my own teaching.	25	38	33	4
	(33	36	23	9)
This course experience increased my understanding of how to use different math/science teaching strategies.	18	53	24	5
	(34	41	18	7)
I will likely share teaching ideas from this course with classmates in 1999-2000.	17	48	26	8
	(30	37	22	10)

Although genetics is traditionally considered a difficult topic by undergraduate non-science students, the *SOH* evaluation results indicate that the course has been well received when compared to other VCEPT-influenced courses. In particular, students in *SOH* report that the course contains a good mixture of breadth and depth in coverage of topics, provides strong connections to other disciplines and to the natural world, includes interesting and intellectually involving concepts, leads to critical thinking about current events, and deals with ethical and social implications in the world. ■

References

[1] "*BIOL 102 The Science of Heredity*: A team approach," *Focus on General Education, VCU College of Humanities and Sciences*, VCU Outreach Publications, (2001) 26-27, Internet: <http://www.has.vcu.edu/students/genedbroc.pdf>.

[2] J.P. Chinnici, "Without This Knowledge, We Could Ruin The World: Scientific Literacy at VCU," *VCU Teaching*, 4(2) (1992) 15-20.

[3] J.P. Chinnici and D.R. Hiley, "Reforming General Education Science at VCU," *Journal of General Education*, **47** (1998) 242-252, Internet: <http://www.vcu.edu/vcuteaching/archives/index.html>.

[4] H.-H. Cho, J.B. Kahle, and F.H. Nordland, "An investigation of high school textbooks as a source of misunderstandings and difficulties in genetics and some suggestions for teaching genetics," *Science Education*, **69** (1985) 707-719.

[5] F.N. Finley, J. Stewart, and W.L. Yarroch, "Teachers' Perceptions of Important and Difficult Science Content," *Science Education*, **66** (1982) 531-538.

[6] K.M. Fisher, J.L. Lipson, A.C. Hildebrand, L. Miguel, N. Schoenberg, and N. Porter, "Student Misconceptions and Teacher Assumptions in College Biology," *Journal of College Science Teaching*, **15** (1986) 276-280.

[7] B. Longden, "Genetics—Are there Inherent Learning Difficulties?" *Journal of Biological Education*, **16** (1982) 135-140.

[8] M.K. Smith, "Teaching Cell Division: Student Difficulties and Teaching Recommendations," *Journal of College Science Teaching*, **21** (1991) 28-33.

[9] M.K. Smith and A.C. Kindfield, "Teaching Cell Division: Basics and Recommendations," *The American Biology Teacher*, **61** (1999) 366-371.

[10] Virginia Collaborative for Excellence in the Preparation of Teachers website, Internet: <http://vcept.longwood.edu/> or <http://www.mas.vcu.edu/g1/vcept/bio/bio102f98.htm>.

[11] G. Bass, "Evaluating Reform Teaching in College Courses—Action Evaluation is Action Research," *The Journal of Mathematics and Science: Collaborative Explorations*, **5** (2002).

CASE STUDIES FROM AN INTEGRATED MATHEMATICS AND SCIENCE COURSE

P.E. McNEIL
Dept. of Mathematics, Norfolk State University
Norfolk, VA 23504

Introduction

In a previous article, the essentials of an experimental, interdisciplinary mathematics and science course was outlined [1]. The course was developed and taught by a team of mathematics and science professors at Norfolk State University (NSU), under the auspices of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), and funded by the National Science Foundation (NSF). The article gave brief descriptions of the investigatory modules developed for the course and the mathematical modeling approach to solving the problems posed in the modules. In this paper, we go into greater detail on some actual problems posed in the modules and the approaches that students used to investigate them. The problems and activities are grouped under headings called "studies" to indicate that they were compiled by studying and observing students in actual classroom situations. The course makes use of an introductory mathematical modeling text [2], however the majority of the course activities are generated from the written modules. Students are given a lengthy bibliography to assist in their investigations, some of the items from which are included in this paper's references [3-8].

The course attracts approximately twenty students per semester, mostly sophomores and some juniors, who use the course as a lower level math or science elective. The prerequisites for the course are two semesters of mathematics and two semesters of laboratory science. The mix of students in the course includes mathematics and natural science majors, as well as elementary and secondary education majors. This diversity of majors contributes to the interdisciplinary flavor that the course attempts to maintain.

Case Studies

Study 1: Exponential and Logistical Curve Fitting — At the outset of the course, students are invited into the world of mathematical modeling through a number of exercises involving curve fitting and linear regression. In a "greenhouse effect" exercise, students are given the following

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 59 - 73

data, which show the rise in the average temperature of the earth each year above that of the base year 1860 over a period of years beginning with the year 1880.

Year	**Average Temperature Rise of the Earth Above the 1860 Figure (°C)**
1880	0.01
1896	0.02
1900	0.03
1910	0.04
1920	0.06
1930	0.08
1940	0.10
1950	0.13
1960	0.18
1970	0.24
1980	0.32

Students are prompted to describe the devastation that would be associated with a rise in average temperature of 7°C above its 1860 value (melting of the polar ice caps, massive flooding, etc.), and then they are challenged to come up with a model of the data which will permit them to predict when the earth's temperature will reach that value should the trend in the chart continue. After some instruction on procedures for finding lines and curves of best fit, some students came up with the model:

$$y = (0.013301236)(1.033447189)^x$$

where x represents the years, zeroed at 1880, and y represents the average temperature above the 1860 value. At this point, students were challenged to solve the equation for x, given that $y = 7$. This presented an excellent opportunity for teaching the value and the utility of logarithms.

In another exercise, students are provided the data in the table below, which gives the distance of each of the planets from the sun and the planet's period of revolution around the sun.

Planet	**Distance, R, From the Sun (millions of km)**	**Period of Revolution, T, Around the Sun (days)**
Mercury	57.9	88
Venus	108.2	225
Earth	149.6	365
Mars	227.9	687
Jupiter	778.3	4,329
Saturn	1427	10,753
Uranus	2870	30,660
Neptune	4497	60,150
Pluto	5907	90,670

Students are then asked to come up with the polynomial equation of the form $y = ax^n$ that "best" models the data. In effect, they are being asked to discover or to verify the well-known Kepler's Third Law which establishes a relationship between a planet's distance from the sun and its period of revolution around the sun. The exercise produces some excitement when students see how closely they can come to deriving Kepler's formula: $T^2 = kR^3$, where T is the planet's period of revolution, R is its distance from the sun, and k is a multiple of the gravitational constant. In one instance, a group of students working cooperatively came up with the model,

$$y = 0.2001x^{1.4997},$$

but were hard pressed to show how closely the latter comes to expressing the law that the square of the period of revolution of a planet around the sun is directly proportional to the cube of its distance from the sun. We took this opportunity to review the basic laws of exponents, and then we had the students square both sides of the model equation to get the result:

$$y^2 = 0.04004x^{2.994}.$$

Now, they were able visually to make the connection with Kepler's formula, and they showed, through elementary error analysis, that their model for the given data varies from the Kepler formulation by less than 5%.

In one of the population growth exercises, students are given the following population data for the United States:

Year	USA Population (millions)
1850	23.2
1860	31.4
1870	38.6
1880	50.3
1890	62.9
1900	76.0
1910	92.0
1920	105.7
1930	122.7
1940	131.7
1950	150.7
1960	179.3
1970	203.2
1980	226.5
1990	252.0
2000	281.0

Next, they are asked to determine the periods in which the growth was approximately exponential and those in which the growth was approximately logistic. The results are predictably varied amongst the student groups. The most interesting part of this exercise occurs when students are asked to cite historical reasons for the rapid growth or the slowed growth in a given period. The approach in the majority of these exercises is admittedly empirical, but the approach lends itself to nudging students toward the theoretical aspects of modeling.

<u>Study 2: Improving the Quality of Water</u> — This section relates to a module that addresses some causes and remedies of water pollution in the Hampton Roads area. The unit begins with a lecture by a representative of the Chesapeake Bay Foundation who emphasizes the importance of oysters to a clean bay and who describes efforts by the foundation to increase the oyster population in the bay. At the end of the lecture, the representative presents a spreadsheet (see Appendix A,

"Oysters in the Chesapeake Bay") that gives information on the oyster density, the fecundity, and the retention and mortality rates of oysters in seven tributaries around the state of Virginia. Given the following definitions and formulas, students are asked to complete the spreadsheet and to make projections concerning the future oyster population in the selected tributaries.

Oyster Density: Number of oysters per square meter of bottom
%Fert: The percentage of eggs fertilized %Fert = 0.49*(Density)^0.72
Fecundity: Number of eggs per female oyster
Area: Area of oyster habitat at the average density given in column 1 of the sheet
Offspring: Number of larvae produced: Female density × fecundity × %Fert × area
Survivors: Number of larvae left after 2 weeks; mortality rate is 99.5% first 2 weeks
%Retention: Percentage of oyster offspring retained for settlement
# of Settlers: Number of offspring that survive to settle in a suitable habitat
Juvenile Mortality: % Mortality of juveniles prior to reaching sexual maturity
New Oysters: Number of oysters reaching sexual maturity after one year

After computing the number and density of the oysters in each of the tributaries at the end of one year, students are now in position to use the new oyster density to project the number of oysters after a second year and for subsequent years. One of the students, a computer science major, became so enthused with this process that he wrote a fairly elegant program in *C++* to project the density of the oysters in each of the tributaries in any given year up to fifty years in the future! The exercise is an excellent one for gaining facility in the use of a spreadsheet. Also, students see the relevance of their projections relative to the future health of the Chesapeake Bay and its environs. A version of the completed chart after one year of propagation is in Appendix B ("Completed Oyster Chart").

<u>Study 3: Tracking the Spread of Diseases</u> — The activities described in this study result from a module entitled, "Epidemics and the Spread of Diseases." In this module, students are provided background and data on some of the dread diseases that plague our society, along with information on some of the epidemic outbreaks of the diseases. Initially, students are presented

with the standard Susceptibles-Infectives-Removals (SIR) model for the spread of diseases which produces a discrete-time collection of difference equations:

$$x_{n+1} - x_n = -kx_n y_n \tag{1}$$

$$y_{n+1} - y_n = kx_n y_n - ry_n \tag{2}$$

$$z_{n+1} - z_n = ry_n \tag{3}$$

where x_n denotes the number of susceptibles (people who are currently uninfected but who may become infected), y_n denotes the number of infectives (people who are infected and capable of spreading the infection), and z_n denotes the accumulated number of removals (persons who died from the disease or who recovered and are now immune) on day n of the epidemic. We make several simplifying assumptions, including: the three groups are mutually exclusive and comprise the entire population being studied; and, there are no births or deaths due to other causes during the epidemic. We further assume that the population size N is fixed throughout the epidemic so that $N = x_n + y_n + z_n$ for all n. The model is particularly useful because if the constants of proportionality, k and r, are known or can be approximated for a population, then values of x_n, y_n, and z_n can be generated on a spreadsheet from initial values. Students illustrate these notions in solving the following problem:

> Suppose that in a population of 1,000 people twenty people are initially immune from a disease and one person is initially infected. Generate values of x_n, y_n, and z_n if it is known that k = .0005 and r = .05. Display your results in a spreadsheet, and generate graphs of each function. Based on your spreadsheet and graphs, approximate answers to the following: How many days will it take for the susceptibles to be eradicated? On what day did the epidemic produce the largest number of infectives? Approximately how long does the epidemic last?

Their solutions typically produce charts and graphs similar to those illustrated in Appendix C ("Introductory Epidemics Problem") and Appendix D ("SIR Epidemic Curves"). In subsequent investigations, students attempt to model specific epidemics by fitting data to these "ideal" SIR curves. Their task, when given data on some epidemic, is to determine values for the parameters k and r in equations (1) – (3) that produce the SIR curves that "best fit" the given data.

Students get the opportunity to apply these notions in an investigation of the Ebola outbreak of 1995 in Zaire, Africa. They are given data in the form of a histogram, downloaded from the Centers of Disease Control website, that contain the number of deaths recorded daily during the 85-day epidemic (see Appendix E). Also, they are instructed that the incubation period for Ebola is between 2 and 21 days, that approximately 77% of infected people usually die from the disease, and that the population size is about N= 900.

Their first task is to generate a table for the removals, z_n. Then, taking the average incubation period to be say nine days, they are led to see that the number of deaths in any nine-day period during the epidemic should be roughly 77% of the number infected on the first day of the period. Using this information, they are able to come up with approximations for k and r for this epidemic. To test the accuracy of their approximations, they generate the theoretical SIR curves for their values of k and r, and then compare them with the given data by way of error analysis. The idea is to juggle the values of r and k until some acceptable level of error is acquired. Using this approach, one student group came up with the values k = .00013 and r = .04542, which yield pretty good results.

<u>Study 4: Studying the Flow of Heat</u> — The activities in this study introduce students to the world of thermodynamics by discussing the problems associated with heat flow in a variety of circumstances. Initially, students are introduced to Newton's Law of Cooling: the change in temperature of a substance is proportional to the difference between the temperature of the substance and room temperature, symbolically:

$$T_{n+1} - T_n = k\left(T_n - R\right). \tag{4}$$

Students then test the law by way of experiments in the physics laboratory involving the cool down rate of a hot liquid. The same experiment is modeled in the classroom using a Texas Instruments Calculator Based Laboratory (CBL) and curve fitting techniques. Their laboratory introduction to Newton's Law is contained in the following instructions relative to a cup of hot liquid:

1. Collect temperature data at two-minute intervals for at least fifty minutes.

2. Plot a graph of the temperature data over time. Describe the curve. Does your curve suggest an asymptote?

3. Test to see if Newton's law holds by graphing (T_{n+1} - T_n) vs (T_n - R). If Newton's Law does hold for your data, what kind of curve should you get? How can you approximate the constant of proportionality, *k*? (Hint: find the slope of a certain regression line.)

At this point, students are asked to verify that the general solution to the difference equation in (4) is:

$$T_n = R + (T_0 - R)(1+k)^n \tag{5}$$

where T_0 represents the original temperature of the liquid. Now, they are led to perform error analysis to determine how closely the data they collected in the cooling experiment approximates that generated by equation (5).

One student, a pre-service teacher, used these notions to develop a lesson plan that he adapted from a scenario he found in *The Mathematical Universe*, by William Dunham [9]. The scenario involves heating a potato ("Mr. Potato Head") in a microwave and then removing the potato prior to students' arrival in a classroom. The removal of the potato simulates the death of Mr. Potato Head and with some clues, students are required to engage in forensic science and estimate the time of death, i.e., the time at which the potato was removed from the microwave.

Study 5: Explorations in Human Genetics — In this final study, the activities are designed to introduce students to the elementary principles of genetics and the application of these principles to the study of certain genetic diseases and other genetically based phenomena. The genetics principles are introduced through individual examples using intuitive probability notions. In this introduction, students become familiar with basic genetic terms and concepts: gene, allele, genotype, phenotype, dominant/recessive traits, etc., and they get some experience in producing and interpreting Punnett squares. This approach extends in a natural way to discussions of population genetics and illustrations of the Hardy-Weinberg Principle. Students examine case studies involving genetic diseases, such as cystic fibrosis, Huntington's disease, Tay-Sach's disease, albinism, and sickle-cell anemia. In a typical example, students compute the probability that two parents who are carriers of the sickle cell anemia trait will produce a child who has the disease or who carries the trait. In another example, students consider a population in which one child in 400 has the sickle cell disease and are asked to find the genotypic frequencies of the normal and abnormal alleles relative to sickle cell anemia in this population. After computing these frequencies for the first filial generation of the population, they are prepared to discuss the question of whether the Hardy-Weinberg Principle appears to hold for the population.

Another activity involves students in an experiment comparing blood type frequencies on Norfolk State's campus with established blood type proportions in the United States and elsewhere. First, they conduct a survey to determine the blood group type of each member of the class. They list the number in each blood group and the blood group frequencies as percentages of the total class size. Next, using the table below, which shows the result of blood type testing among certain populations, they calculate the expected numbers in the blood groups based on the proportions listed in the table. Finally, they use the chi-square test with three degrees of freedom to determine if there is a significant difference between the expected and the observed numbers in the blood groups. Students are encouraged to increase the size of their sample to get better results.

Proportions of ABO Phenotypes in Selected Populations

Population	**A**	**B**	**AB**	**O**
Chinese	0.27	0.23	0.06	0.44
French	0.45	0.09	0.04	0.42
Indians	0.25	0.38	0.07	0.30
Nigerians	0.21	0.23	0.04	0.52
US Blacks	0.27	0.21	0.04	0.48
US Whites	0.41	0.10	0.07	0.52

As a part of their study of genetic diseases, students obtain first-hand information about the research efforts at the Eastern Virginia Medical School, Norfolk, VA, to isolate a diabetes gene and, after viewing a Public Broadcast System video, they discuss the ethical implications of the discovery of a breast cancer gene. Their final challenge is the gathering of information on the Internet about the Human Genome Project. A good deal of excitement resulted from the public announcement, while we were engaged in these studies, that scientists had completed the mapping of the entire human genetic system.

Evaluation and Conclusion

The evaluation of the course is based on three items: a) student participation in group activity; b) student performance on examinations covering basic mathematics and science skills; and, c) student evaluation questionnaires. Student evaluation surveys are conducted after the completion of each module, and one final questionnaire is administered at the end of the course. Similar final questionnaires are administered in three traditional sophomore/junior level courses in mathematics, biology, and chemistry, each taught by a member of our teaching team.

We find that students, after an initial period of adjustment, adapt very well to working in cooperative groups. In order to discourage students from depending on one or two persons in the group to do all of the work, we require a "division of labor" statement to be included with each of their submissions. Students soon realize that each of them must contribute his/her expertise in order for his/her group to successfully complete a module.

Relative to item b), we identify items on the final examination which appeared to deal with basic mathematics and science concepts and skills. We do the same in the three regular courses. We found that performance on these items in the interdisciplinary course is comparable to that in the three regular courses. Our conclusion is that the innovative, experimental elements in the course are not detrimental to the basic skill building that should accompany a mathematics or science course.

As a result of our evaluation surveys, we find that students in the interdisciplinary course display great enthusiasm for the course topics and methodology. They appreciate the relevance of our modules to real-world problems and issues, and they tend to be surprised and amazed at the interconnectedness of the disciplines. Moreover, we discern from the surveys a definite increase in students' perceived confidence in their ability to do mathematics and science and we observe, especially in the cooperative group activity, an increase in their readiness to tackle challenging problems.

The success that we have enjoyed in the activities outlined in these studies suggest to us that students with minimal preparation in mathematics and science can become involved in significant mathematics/science concepts. We believe that the secret to success in a course such as ours is first, to involve students in interesting and relevant problems and second, to begin at a concrete level at which they can easily function, gradually leading them to the conclusions and abstractions that we wish them to comprehend. It is gratifying to us that the course has become a popular one for students preparing to teach. Our hope is that when these students become masters in their own classrooms they will employ these methods with their own students. Gratifying also is the evidence, provided in this course, that both liberal arts majors and education majors can coexist and be mutually beneficial in the same classroom setting.

The success of our efforts has led to the approval of a follow-up course using the same format. We look forward to beginning this new endeavor during the Spring 2003 semester. ■

References

[1] P.E. McNeil, "A New Interdisciplinary Mathematics and Science Course," *The Journal of Mathematics and Science: Collaborative Explorations*, **2**(2) (1999) 27-32.

[2] J. Berry and K. Houston, *Mathematical Modeling*, Edward Arnold, London, 1995.

[3] T. Audesirk and G. Audesirk, *Biology: Life on Earth*, Prentice Hall, Upper Saddle River, NJ, 1996.

[4] N.G. Cooper (ed.), *The Human Genome Project: Deciphering the Blueprint of Humanity*, University Science Books, Mill Valley, CA, 1994.

[5] S.P. Gordon, et al., *Functioning in the Real World: A Precalculus Experience*, Addison-Wesley, Reading, MA, 1997.

[6] I.D. Huntley and J.G. James (eds.), *Mathematical Modeling: A Source Book of Case Studies*, Oxford University Press, New York, 1992.

[7] J. Trefil and R. Hazen, *The Sciences: An Integrated Approach*, John Wiley and Sons, Inc., New York, 1995.

[8] M.A. Tribe, I. Tallan, and M.R. Eraut, *Basic Biology Course: Book 12 Case Studies in Genetics, Unit 5 Aspects of Heredity*, Cambridge University Press, New York, 1978.

[9] W. Dunham, *The Mathematical Universe: An Alphabetical Journey through Great Proofs, Problems and Personalities*, John Wiley and Sons, Inc., New York, 1994.

APPENDIX A – Oysters in the Chesapeake Bay

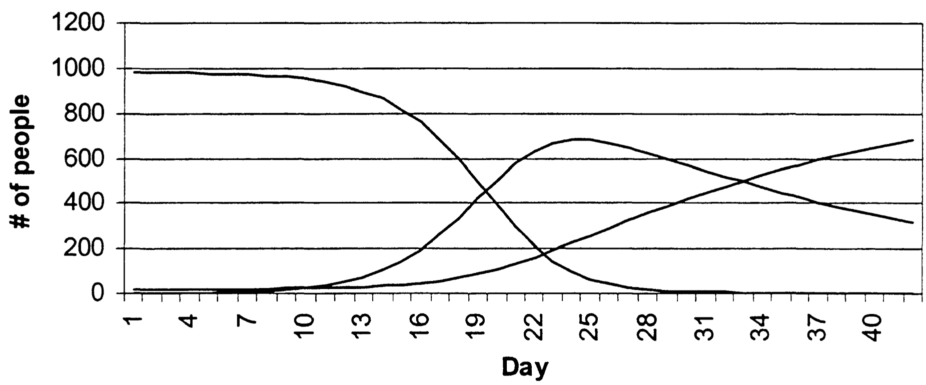
Area	Oyster Density (Oyst per m^2	% Fert	Fecundity Eggs/Fem	Area m^2	Offspring	Survivors	% Retention	# Settlers	%Juv. Mort.	New Oysters
James River	30.9	5.8	10^6	12147	1.1x10^10	5.4x10^7	90	4.9x10^7	99	5.4x10^7
Rappahannock River	1.7		10^6	12147			50		99	
Piankatank River	0.7		10^6	24294			90		99	
Great Wicomico River	36.6		10^6	44539			90			
Coan River	6.3		10^6	12147			75		99	
Yeocomico River	0.9		10^6	40490			75		99	
Tangier Sound	0.4		10^6	336067			25		99	
	Density of New Oysters (number of new/area)		**% Mortality of Adult Oysters (Fishing + Natural)**		**Adult Density Ater 1 year**		**Final Density (Adult + New)**		**Total Oysters After 1 Year**	
James River	40.3		65		10.8		51.1		620712	
Rappahannock River			50							
Piankatank River			40							
Great Wicomico River			50							
Coan River			50							
Yeocomico River			20							
Tangier Sound			5							

APPENDIX B - Completed Oyster Chart										
Region	**Oyster Density (Oyst per m^2**	**% Fert**	**Fecundity Eggs/Fem**	**Area m^2**	**Offspring**	**Survivors**	**% Retention**	**# Settlers**	**%Juv. Mort.**	**New Oysters**
James River	30.9	5.8	1.0E+06	12147	1.1E+10	5.4E+07	90	4.9E+07	99	4.9E+05
Rappahannock River	1.7	0.7	1.0E+06	12147	7.4E+07	3.7E+05	50	1.9E+05	99	1.9E+03
Piankatank River	0.7	0.4	1.0E+06	24294	3.2E+07	1.6E+05	90	1.5E+05	99	1.5E+03
Great Wicomico River	36.6	6.5	1.0E+06	44539	5.3E+10	2.7E+08	90	2.4E+08	99	2.4E+06
Coan River	6.3	1.8	1.0E+06	12147	7.1E+08	3.5E+06	75	2.6E+06	99	2.6E+04
Yeocomico River	0.9	0.5	1.0E+06	40490	8.3E+07	4.1E+05	75	3.1E+05	99	3.1E+03
Tangier Sound	0.4	0.3	1.0E+06	336067	1.7E+08	8.5E+05	25	2.1E+05	99	2.1E+03
	Number of Original Oysters (Density H Area)		**% Mortality of Original Oysters (Fishing + Natural)**		**Remaining Original Oysters**		**Total Oysters After 1 Year**		**Oyster Density After 1 Year**	
James River	3.8E+05		65		1.3E+05		6.2E+05		51.1	
Rappahannock River	2.1E+04		50		1.0E+04		1.2E+04		1.0	
Piankatank River	1.7E+04		40		1.0E+04		1.2E+04		0.5	
Great Wicomico River	1.6E+06		50		8.2E+05		3.2E+06		72.2	
Coan River	7.7E+04		50		3.8E+04		6.5E+04		5.3	
Yeocomico River	3.6E+04		20		2.9E+04		3.2E+04		0.8	
Tangier Sound	1.3E+05		5		1.3E+05		1.3E+05		0.4	

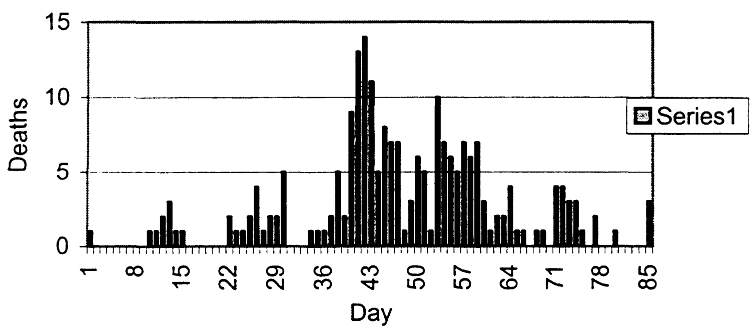
APPENDIX C - Intro. Epidemics Problem

$N = 1000$ DAY	$x_0 = 979$ x_n(SUS)	$y_0 = 1$ y_n(INF)	$z_0 = 20$ z_n(REM)
0	979	1	20
1	979	1	20
2	978	2	20
3	977	3	20
4	975	4	20
5	973	6	21
6	970	9	21
7	966	13	21
8	960	18	22
9	951	26	23
10	939	37	24
11	921	53	26
12	897	74	29
13	864	104	32
14	819	144	38
15	760	195	45
16	686	260	55
17	597	336	68
18	497	419	84
19	392	502	105
20	294	576	130
21	209	632	159
22	143	666	191
23	96	680	224
24	63	679	258
25	42	666	292
26	28	647	325
27	19	624	358
28	13	598	389
29	9	572	419
30	6	546	447
31	5	521	475
32	3	496	501
33	3	472	526
34	2	449	549
35	2	427	572
36	1	406	593
37	1	386	613
38	1	367	632
39	1	349	651
40	1	331	668
41	0	315	685

APPENDIX D
SIR Epidemic Curves



Appendix E
Daily Ebola Deaths in the Zaire Epidemic of 1995



ENHANCING FINITE MATHEMATICS WITH GLOBAL AWARENESS

D.L. HYDORN
Dept. of Mathematics, Mary Washington College
Fredericksburg, VA 22310

Abstract

This paper describes the project of modifying the course, *Finite Mathematics*, to meet a Global Awareness course requirement. The components of the revised course are described, including topics, in-class activities, and student evaluation methods, along with a summary of the results of a general education assessment of the course.

Introduction

Like other liberal arts colleges, Mary Washington College (MWC) includes a mathematics requirement in its general education program. To meet this requirement, courses must develop "an understanding of mathematical thought and the ability to conceptualize and apply mathematical logic to problem-solving." Students must take two courses from within this general education goal, one of which must be offered by the Department of Mathematics. *Finite Mathematics* is one course that meets this requirement. This course is typically taken by students in non-science disciplines and assumes that students have completed high school algebra. The goals of this 100-level course are to demonstrate how mathematics is part of our everyday lives, to help students gain a mathematical perspective, and to accomplish these tasks while easing the math anxiety many students feel. While the topics included in *Finite Mathematics* can provide the means for accomplishing these tasks, teaching the course with a global awareness emphasis can help provide an incentive for learning those topics. It can also enhance students' interest in and appreciation for the mathematics they are learning.

The general education program at MWC also includes a requirement that students take two courses that carry a Global Awareness (GA), Across-the-Curriculum (ATC) designation. A course may receive this designation after a review by the Global Awareness Committee to assess the extent to which it meets the GA requirements: (1) awareness and knowledge of global issues, (2) respect for other languages and cultures, and (3) appreciation of the United States in its international context. Each of these goals has a number of objectives that provide suggestions for how that goal may be met. Although a course need not meet all of the objectives under each

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 75 - 88

of the goals to receive GA designation, it must meet all three goals. A GA course may be within any discipline and may be at any level.

As first taught at MWC, *Finite Mathematics* included sets, counting, and probability and logic, taking advantage of the underlying similarity in the structure of these topics. While mathematicians can recognize and appreciate this similarity, most students who take this course do not. As promoted by the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), instructors began to experiment with adding and/or replacing topics and with adding an ATC designation. The alternate topics depend on the interests and expertise of individual faculty and include graph theory, consumer mathematics, number systems, voting schemes, statistics, patterns, and tessellations. In addition to a GA ATC designation added by one faculty member, two other faculty members have added a Speaking Intensive ATC designation to their sections of this course.

As well as being one of a group of courses that meets the mathematics general education requirement, *Finite Mathematics* is also a required course for Elementary Education students at MWC. In a recent offering of this course, approximately 13% of those enrolled were in the Education program, which is roughly twice the percentage of Education students campus-wide. The general nature of these topics provides a good foundation for developing early math skills. When taught as a GA course, the topics further provide vast enrichment opportunities through the mathematical exploration of other cultures and countries.

As a GA course, *Finite Mathematics* is divided into two parts. Topics were chosen that offer a way either (1) to compare how cultures have developed and use number systems or (2) to compare cultures or countries using mathematics. In the first part of the course, the topics are further divided into two main sections: (1) development of counting, numbers, and number systems; and, (2) the mathematics of symbols and patterns. The second part also has two sections: (1) sets and counting, and (2) probability and statistics. By first showing students how numbers and number systems were developed, they gain an appreciation for the numbers and mathematics that are a part of their daily lives. Using sets, probability, and statistics together to compare countries provides students with a mathematical perspective of the world around them. Finally, the GA emphasis provides an engaging environment and a unified purpose that can help students to overcome their math anxiety. The topics and activities for each of these four sections are described in detail below, along with methods of instruction. Student evaluation and an assessment of the course as a general education course are also discussed. See Appendix A for a list of web resources.

The Development of Counting and Number Systems

By looking at and working with number systems from other cultures, students gain an understanding of how numbers were developed and an appreciation for the different types of number systems.

Topics — This section of the course begins by addressing the question, is counting universal? Students consider the existence of a "number sense" and the "limit of four" that is prevalent in many number systems [1,2]. Class discussions center on reasons why early humans might need to know how many they had of something, leading to the use of mediating objects such as tally sticks and pebbles [1-4]. Through examples, students are led to discover the limitations of these methods. The five uses for numbers (number, size, form, order plus unique identification) are then discussed. Students are encouraged to find examples in their daily encounters with numbers. In the preface of Brian Butterworth's *What Counts*, a tour through just one page of a daily newspaper reveals 51 separate numbers; a convincing example of just how prevalent and important numbers are in our lives [5]. Early counting systems, such as those used by the two-counting and five-counting cultures described in *Pi in the Sky*, are discussed along with number words from different cultures [1]. Students are asked to consider the analytical, linguistic, and writing skills needed to develop a useful number system. The development of simple grouping number systems from basic tallies is explored, along with the similarity between these systems and the "five-barred gate" method of tallying still used today [2]. A comparison is made between the four types of number systems: simple grouping, ciphers, multiplicative grouping, and positional [1-3]. As an introduction to positional systems, bases other than 10 are explored. Bases less than 10 seem to be easier for students to grasp so more time is spent preparing students for the base 20 Mayan and base 60 Babylonian systems. The historical development and use of ten separate number systems is examined: Egyptian hieroglyphs, hieratic and demotic ciphers, Chinese brush form and counting rods, Babylonian, Mayan, Roman, and the Greek Ionian and Attic systems. By comparing how these different number systems work, students discover the tradeoffs that result between memorizing more symbols compared to having fewer symbols to write and the relative ease of performing computations in one system compared to another. The development and use of fractions, decimals, and negative numbers [2,3] in some number systems are also examined, along with a history of zero [6].

Activities — To record their daily encounter with numbers, students create a scrapbook of examples for each of the five uses for numbers along with number words and symbols from other number systems. To learn more about oral counting, students investigate the counting system used by Hawaiians [7] and discover its similarities to a ciphered number system. Students then compare the finger counting system used by the Masai [4] with the system described by the Venerable Bede [1,2,4,7]. To study more about mediating objects, students investigate the Incan quipu and other knot-and-string methods of counting [2,4,7]. To ease difficulties encountered in dealing with a system other than base 10 and with a different set of numerals, students can create a base four system using O, I, V, N, and M. For more practice with bases other than 10, students investigate the base 20 Kaktovik Inupiaq numbers created by school children to support their oral counting system. The Chinese counting rod number system can be found in the early use of "Pascal's" triangle by the Chinese and can be used to expand students' practice with this system [2,7]. Students can construct a simple Chinese abacus and learn to do basic calculations [2,8]. The use of an abacus in other cultures can also be explored. Figure 1 shows an abacus created in *Microsoft Word* that was created for a worksheet and could easily be incorporated in an online activity.

Number stories are common in many cultures and countries. Examples include Horus' eye in ancient Egypt [2,4], the stories about King Shirham of India and about the Tower of Brahma [9], and the collection of stories in *The Man Who Counted* [10]. Students can investigate the underlying mathematics behind these stories or create number stories of their own. Further explorations can include number mysticism and gematria [2,3], the uses of numbers in cryptology [2], the history of *pi* [11], and number games and puzzles [2]. *Multicultural Mathematics* [12] provides many ideas for activities to enrich lessons in the early and middle school grades, while *The Crest of the Peacock* [13] provides a history of non-European mathematics.

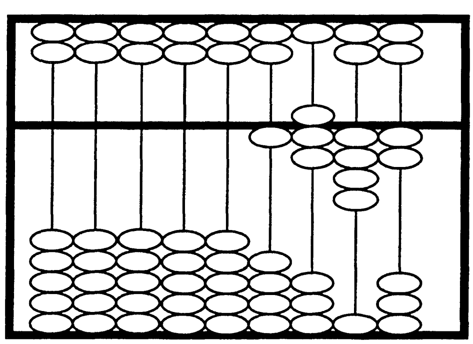


Figure 1 Chinese Abacus showing the number 1,742.

The Mathematics of Pattern and Design

By studying the basic symmetry operations, students explore the similarities in designs and patterns created and used by different cultures.

Topics — Beginning with the operations of rotation, reflection, translation and glide translation, students investigate the point, line, and plane groups [14,15]. Early and current methods of symbolism are studied for their symmetric properties, including symbols created by mimicking patterns from nature [16] and the development of sign structures [17]. Students are asked to consider the cultural use of patterns for aesthetic properties and for communication. Tessellations [14] and the work of Escher [18] are also explored.

Activities — Students are asked to create and identify patterns from each of the different point, line, and plane groups. The software package *Kaleidomania!* is especially useful in helping students explore the operations used to create different patterns. In addition to allowing students to create different patterns, *Kaleidomania!* also has a feature that shows how the pattern is generated. Figure 2 shows examples of point and line group patterns created using this software.

(a) Group 2mm pattern (two reflections)

(b) Group mt pattern (reflection and translation)

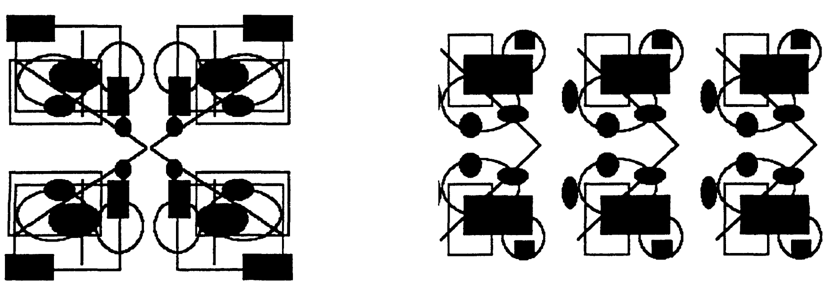


Figure 2 *Kaleidomania!* examples.

Students can explore the mathematical structure of logos in use today, many of which have been used by other cultures. For example, the logo for Mitsubishi is a Nordic rune used to induce madness [15] and is also called the triceps, meaning divine power [17]. Many cultural uses of patterns provide students with wonderful opportunities to explore their own and others' backgrounds. A few examples include: Russian Easter eggs; Mexican, Japanese, German paper cutting; American Indian basket weaving; Oriental carpets; American quilt patterns; and, Celtic knots. To record their explorations into patterns and symbols, students create a scrapbook of patterns and designs from different sources.

Sets and Counting

Organizing objects into collections with similar properties is an activity common to many human endeavors. By studying the properties of sets, students investigate how sets can be used to examine the similarities of different countries or cultures.

Topics — The topics in this section follow very closely the material provided in many finite mathematics or mathematics for the liberal arts texts. The text used for this course is found in Bello and Britton's *Topics in Contemporary Mathematics* [19]. Topics for sets include the basic definitions of set, universal set, empty set, and subset, along with the set operations and their properties and Venn diagrams. Special attention is paid to using Venn diagrams to summarize the results of surveys. Topics for counting include tree diagrams and the sequential counting principle, along with combinations and permutations.

Activities — To explore the use of sets as a problem solving tool, students choose a continent or region and create subsets of countries or states with similar properties that can be identified using an atlas (e.g., countries that have a coastline on the Atlantic, share a border with a given country or state, or include a specific mountain range). On a larger scale, students conduct a "survey" of the world's nations concerning the status of two international agreements, then create a table and Venn diagram to summarize the results, along with colored-in world maps to identify each of the four subgroups of countries created. The software *Amiglobe* or the CIA website can be used to conduct the survey and to locate each of the countries for the maps. An example survey and map are shown in Figures 3 and 4. A website for the map and the *Amiglobe* and CIA websites are given at the end of this paper.

	Signed International Agreement?	
Environmental Issue?	Yes	No
Yes	55	5
No	100	33

Figure 3. Results of a survey of countries that have signed the International Agreement on Desertification and those that currently have this environmental problem.

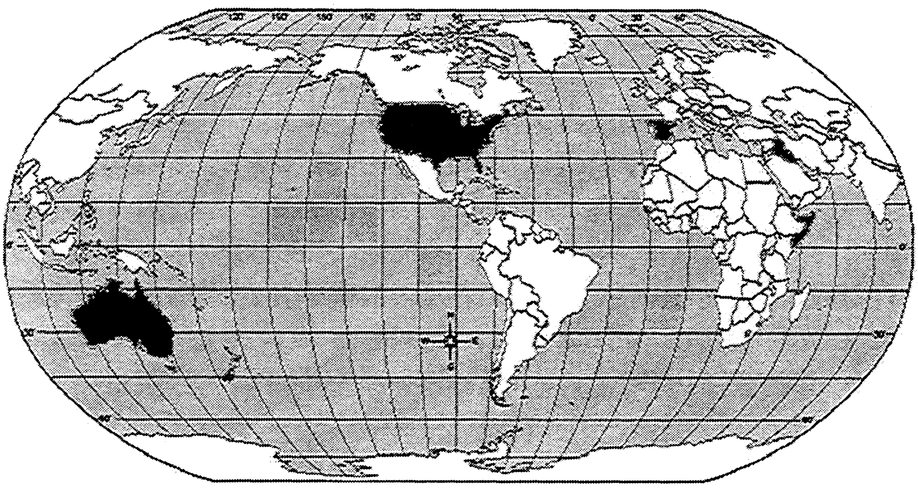


Figure 4. Countries that have not signed the International Agreement on Desertification, but have this environmental problem.

Students can also conduct a survey of other students on their opinions or knowledge of world issues and summarize the results as in the preceding example. Activities for counting topics are harder to "match" to a GA theme, but include skill development, particularly for preparing students for learning probability.

Probability and Statistics

The skills of reading and interpreting graphs, as well as selecting and making an appropriate graph for a given data set, are becoming increasingly important as more and more quantitative information is presented using graphs. In this section, students learn to use basic graphical measures and descriptive statistics to compare cultures or countries.

Topics — As with sets and counting, the topics for this section follow very closely the material available in many finite mathematics and liberal arts mathematics texts. Topics include the definitions of probability and independent events, methods of assigning probability, probability rules, measures of center, and basic graphical techniques. There are also other useful texts for exploring the uses of different graphs [20-25].

Activities — To investigate the uses of different graphs, students are given a data set and asked to decide on a "best" way to display the data along with an explanation for their choice. To explore the characteristics of different countries, students can compare mortality tables or pyramid charts that show the age distribution by sex. The global math activities in the workbook [26] provide many other graphical methods for comparing countries. To record their daily encounters with different graphs, students collect example charts, graphs, and comparative statistics for different countries. Students can also use software such as *Excel* or SPSS© to create graphs for data collected for a selected country to compare to the United States. Data for these projects can be collected using *Amiglobe* or the CIA website. Figure 5 shows a sample graph produced using *Excel*.

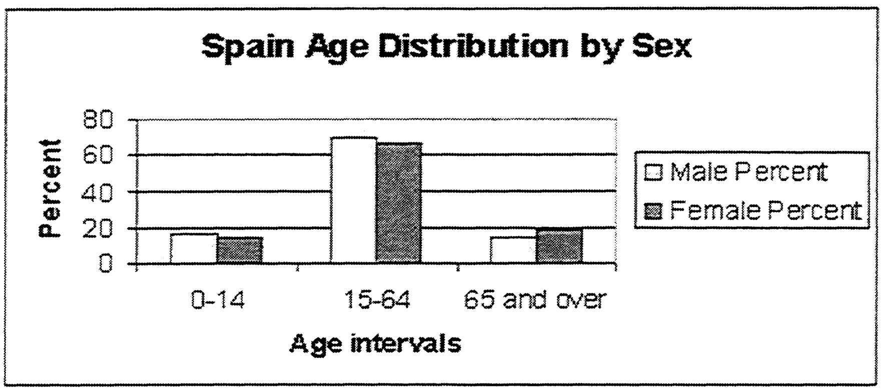


Figure 5. Age Distribution by Sex for Spain.

Teaching Methods

The course is taught using modified lectures, where new material is interspersed with examples and activities. Class handouts were developed to supplement textbook [19] material on the development of numbers and number systems. The text used for this course does not include any material on patterns and symmetry, so class handouts were developed for these topics as well. The text does cover sets, counting, probability, and statistics so lectures on these topics are based on the text material. Most examples, activities, and assignments include a global theme. Whenever possible, current events are incorporated into class activities and discussions. A typical class might start with an introduction to new terminology and notation followed by examples and an in-class activity. Review summaries and practice problem worksheets are distributed before each exam. Because emphasis was placed on the underlying mathematics, and not on the memorization of symbols or labels, students are given handouts with each of the number systems and patterns studied to use for in-class activities, quizzes, and exams on these topics.

Student Assessment

In both the GA and non-GA versions of this course, students are assessed using in-class tests, take-home quizzes, and projects. Take-home quizzes consist of questions similar to those on the tests and the projects give students the opportunity to further explore topics from class. The biggest differences between the two versions of the course are in the tests and projects. In the non-GA course, four tests are given (Sets, Logic, Counting, and Probability) comprising 80% of the grade. Two individual class projects are assigned. For the first project, students conduct a survey of their classmates on a topic of their choice and organize the results in a Venn diagram. For the second, students design a scratch-off style lottery ticket, including the number and types of winning tickets, and calculate the probability of winning and the average winnings. In the GA course, three tests are given (Numbers and Numeration systems, Patterns and Sets, and Counting, Probability, and Statistics) accounting for 60% of the grade. Two group projects are also assigned. For the first project, students conduct a "survey" of countries on two international agreements and organize the results in a Venn diagram. They also investigate the terms of the agreement and produce maps to show the four subsets of countries identified by the Venn diagram. For the second project, students produce graphs depicting the population distribution by age and gender, birth and death rates, and the sex ratio at birth for a country of their choice to compare to graphs made for these variables for the United States. They also create a histogram for a variable of their choice to show the distribution for all countries and compare the United States and their country within that distribution.

Grade distributions for one section of each version of this course are provided in Table 1. The GA distribution is from Spring 2001 while the non-GA distribution is from Fall 1998. Grade distribution for all 100- and 200-level courses, including *Calculus I, II* and *III*, *Introduction to Statistics*, and *Finite Mathematics* (*MATH 110*), from Spring 2001 and Fall 1998, are also given. Although grade distributions vary by instructor and by course, students in the GA version of *Finite Mathematics* did as well or better than students in the non-GA version.

Table 1
Grade Distributions (percentages) by Course and for all Lower Level Mathematics Courses

	Spring 2001		Fall 1998	
Grade	*MATH 110* GA	All lower-level math courses	*MATH 110* Non-GA	All lower-level math courses
A	26	31	17	25
B	52	34	58	35
C	19	16	17	29

Course Assessment

As part of the evaluation of its general education program, MWC has conducted a survey of student course perceptions. The survey consists of ten pairs of statements to which students respond affirmatively if they agree with the statement. The first statement in each pair asks students to address the effectiveness of the particular course in meeting general education course goals while the second asks students to assess the impact of the course on their learning in that area. Ten of the twenty statements are relevant for evaluating the GA version of *Finite Mathematics*. The results for these questions (percentage of respondents who agree with the statement) from the Spring 2001 and Summer 2002 are provided in Table 2. A total of seven sections of *Finite Mathematics* were offered in the Spring 2001, one of which had the GA designation. Two sections of *Finite Mathematics* with a GA designation were also taught during the Summer 2002.

The results suggest that students in the GA section respond as favorably as other *MATH 110* students to most of these statements and respond much more favorably to others. In particular, for the statements regarding the global nature of the course and relating subject matter to other disciplines, students in the GA sections report a substantially larger proportion of yes responses. Because the general education survey was designed to assess the complete array of general education course offerings, some questions may not be relevant for all courses. Consequently, some faculty instruct their students not to answer questions that are not pertinent to their course. While some of the *Finite Mathematics* instructors from the Spring 2001 may have omitted the questions on the global nature of the course and on how the course relates to other disciplines, the high percentage of yes responses for the GA sections indicates the GA designation is meeting these general education goals.

Table 2
Summary of General Education Course Evaluation for Finite Mathematics (percent yes)

Statement	Spring 2001 All sections n = 160	Spring 2001 GA section only n = 26	Summer 2002 Two sections both GA n = 16
Would you agree that the essence of this course is expressed in the description of a Goal 2 course?	91	88	94
I have gained in my understanding of mathematical thought.	80	77	81
In this course, an effort was made to present broad, even global, connections of this subject matter.	23	100	94
I have gained a better understanding of the broad, even global, connections of this subject matter.	20	88	94
In this course, an effort has been made to relate the subject matter to other fields of study.	56	83	75
I have gained a better understanding of how the field of study represented by this course is related to other fields.	57	75	81
This course has provided an introduction to the field it represents.	84	84	87
I have acquired an understanding of the basic concepts of this field of study.	86	88	93
This course has covered a range of topics that are clearly part of this field.	90	92	94
I have gained an appreciation for the breadth of areas covered by the field of study represented by this course.	79	81	94

Conclusion

The benefits for students taking the GA version of *Finite Mathematics* include a more focused learning experience and a greater emphasis on applications. The emphasis placed on other cultures promotes a greater appreciation for the development of numbers and mathematics. The topics covered also provide students with the means for quantitatively comparing different countries. For faculty, the benefits of teaching a GA (or other ATC designated course) include an opportunity to incorporate personal interests and to engage students more in their learning. A GA emphasis also provides a convenient method of incorporating more real-world activities and discussion into mathematics instruction.

In addition to the continued assessment of students' perceptions about the effectiveness of the GA version of *Finite Mathematics* in meeting general education course goals, additional work on this project will include collecting more examples of global awareness activities and topics to expand the course content, particularly for the sections on sets and counting, and for additional projects in statistics. This additional material will be combined with the examples and assignments described in this paper into a Global Awareness workbook for *Finite Mathematics*.■

References

[1] J.D. Barrow, *Pi in the Sky: Counting, Thinking and Being*, Clarendon Press, Oxford, 1992.

[2] G. Ifrah, *The Universal History of Numbers: From Prehistory to the Invention of the Computer,* John Wiley and Sons, New York, 2000.

[3] D.M. Burton, *Burton's History of Mathematics,* Wm. C. Brown, Dubuque, IA, 1995.

[4] D. Guedj, *Numbers: The Universal Language*, Harry N. Abrams, Inc., New York, NY, 1997.

[5] B. Butterworth, *What Counts: How Every Brain is Hardwired for Math,* The Free Press, New York, NY, 1998.

[6] R. Kaplan, *The Nothing That Is: A Natural History of Zero,* Oxford University Press, New York, 1999.

[7] F.J. Swetz, *From Five Fingers to Infinity: A Journey through the History of Mathematics*, Open Court Publishing, Peru, IL, 1994.

[8] J. Dilson, *The Abacus,* St. Martin's Press, New York, NY, 1968.

[9] G. Gamow, *One Two Three... Infinity: Facts and Speculations of Science,* Viking Press Bantam Books, New York, NY, 1947.

[10] M. Tahan, *The Man Who Counted: A Collection of Mathematical Adventures,* W.W. Norton and Company, New York, NY, 1972.

[11] D. Blatner, *The Joy of π,* Walker Publishing Company, Inc., New York, NY, 1997.

[12] D. Nelson, G.G. Joseph, and J. Williams, *Multicultural Mathematics: Teaching Mathematics from a Global Perspective,* Oxford University Press, Oxford, 1999.

[13] G.G. Joseph, *The Crest of the Peacock: The Non-European Roots of Mathematics,* Princeton University Press, Princeton, NJ, 2000.

[14] K. Devlin, *Mathematics: The Science of Patterns,* Scientific American Library, W.H. Freeman and Company, New York, NY, 1994.

[15] P.S. Stevens, *Handbook of Regular Patterns,* MIT Press, Cambridge, MA, 1981.

[16] P.S. Stevens, *Patterns in Nature*, Little, Brown and Company, Boston, MA, 1974.

[17] C.G. Liungman, *Dictionary of Symbols,* ABC-CLIO, Inc., Santa Barbara, CA, 1999.

[18] F.H. Bool, J.R. Kist, J.L. Locher, and F. Wierda, *M.C. Escher His Life and Complete Work,* Harry N. Abrams, Inc., New York, NY, 1981.

[19] I. Bello and J.R. Britton, *Topics in Contemporary Mathematics,* Houghton Mifflin Company, Boston, MA, 2001.

[20] R.L. Harris, *Information Graphics: A Comprehensive Illustrated Reference,* Oxford University Press, New York, NY, 1999.

[21] G.T. Henry, *Graphing Data: Techniques for Display and Analysis,* Sage Publications, Thousand Oaks, CA, 1995.

[22] E. Tufte, *Envisioning Information,* Graphics Press, Cheshire, CT, 1990.

[23] E. Tufte, *Visual Explanations: Images and Quantities, Evidence and Narrative,* Graphics Press, Cheshire, CT, 1997.

[24] E. Tufte, *The Visual Display of Quantitative Information,* Graphics Press, Cheshire, CT, 2001.

[25] M. Weaver, *Visual Literacy: How to Read and Use Information in Graphic Form,* Learning Express, New York, NY, 1999.

[26] N. Boutis and P. Wasserman, *Multiplying People, Dividing Resources,* Population Connection, Washington, DC, 2002.

Appendix A

MWC General Education Requirements
http://www.mwc.edu/acsv/Level2Pages/GenEd_Sub_Pages/BABS98to01.htm

The Development of Counting and Numbers:

The History of Mathematics in the Americas
http://www.saxakali.com/COLOR_ASP/historymam.htm
Base Value Numbers http://www.psinvention.com/zoetic/basenumb.htm
Egyptian Number Translation http://www.psinvention.com/zoetic/tr_egypt.htm
The Maya Mathematical System http://www.mayacalendar.com/mayacalendar/f-mayamath.html
Kaktovik Inupiaq numerals http://www.col-ed.org/smcnws/potlatch/ak5.html
History of the abacus http://bethany.davis.students.noctrl.edu/5pagepaper.htm
A virtual abacus http://hometown.aol.com/edhobbs/applets/abacus/index.html

The Mathematics of Pattern and Design:

Kaleidomia! http://www.keypress.com/catalog/products/software/Prod_KaleidoMania.html

Sets and Counting:

Amiglobe http://amiglobe.com/
CIA website http://www.cia.gov/cia/publications/factbook/
Outline maps of the world http://www.eduplace.com/ss/ssmaps/wrldcount.html

THE USE OF DRAMATIC DEMONSTRATIONS TO ENHANCE THE MOTIVATION AND LEARNING OF CHEMISTRY STUDENTS

H.A. ROWE
Dept. of Chemistry, Norfolk State University
Norfolk, Virginia 23504

Abstract

As part of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) project, a series of demonstrations was incorporated into *Chemistry 100: Man and Environment*, a science course taken by non-science majors including many prospective K-12 teachers. Dramatic chemical demonstrations were first presented to the undergraduate students by the instructor, and then they used demonstration activities to teach each other during the semester. Finally, these undergraduates presented to the K-6 students in the Norfolk Statue University (NSU) Summer Children's College. The perceptions of science by the undergraduates at the beginning and end of the course were assessed using a questionnaire. The responses of the K-6 students in the Children's College were assessed through informal interviews and audience response. The use of these demonstrations seemed to change the perception of science held by the undergraduate students. In addition, this limited assessment indicated that these demonstrations may have helped more of the undergraduates consider teaching as a career option.

Introduction

Many students have the impression that science and mathematics are boring, "dry," and difficult subjects. Often these views seem to arise from a feeling that science and math are "ivory tower" subjects very much removed from applications to the "real world." Unfortunately, many of these students had a distasteful experience with these subjects during their middle or high school educational experience. College science and mathematics courses are often taught by simply using a textbook and a series of lectures to cover the required material. Chemistry teachers are like any group of people—some tall, some short; some male, some female—and some more talented and dedicated than others. It takes a very dedicated and enthusiastic teacher to give the students meaningful and motivated exposure to chemistry teaching through a traditional lecture-based course. In fact, many university instructors/professors have never had any formal instruction on how to teach and their success as educators is understandably varied. Technology can help assist in instruction, but sometimes students get "caught up" in the technology itself rather than the concepts addressed by that technology [1,2].

Methods

A section of *Chemistry 100: Man and Environment* (*CHM 100*), an introductory survey of chemistry for non-science majors (usually predominately freshman), was taught using a variety of in-class chemistry demonstrations. Initially, the instructor gave the demonstrations and closely linked them to the current topics in the accompanying lecture. During the middle of the course, each undergraduate was assigned a demonstration to explain and give to the class. Finally, the students in teams of three gave demonstrations to several classes of K-6 students in the NSU Summer Children's College. These were followed by discussions at a level appropriate to the age group. The choice of demonstrations were made by selecting from a list provided by the instructor. The undergraduate met with the instructor one week prior to the demonstration to prepare the solutions/equipment, discuss the safety implications, and present the demonstration to the instructor. The undergraduate was awarded a quiz grade for this activity, graded on safety and presentation. The list of available activities are outlined below:

<u>Vacuum Pump Demonstrations</u>
- expansion of balloon/marshmallow
- boiling of water at room temperature
- lack of sound in a vacuum

<u>Molecular Properties</u>
- conductivity
- "electric" pickle

<u>Chemical Kinetics</u>
- apparent "stopping of fan" with strobe
- surface area effects of permanganate/glycerol reaction

<u>Acid/Base</u>
- Universal indicator changes
- Acid Rain

<u>Oxidation/Reduction</u>
- electrolysis of water
- hydrogen peroxide/KI reaction
- burning of magnesium
- chemiluminescence

The Demonstrations

The demonstrations were evaluated for safety concerns prior to their choice for delivery. The safety of each activity was discussed thoroughly before each demonstration (by both the instructor and undergraduate students), and the implications of waste disposal and pollution were addressed at each level. Safety goggles were worn at all times and appropriate safety measures were taken. The details of these activities are well known in chemistry and can be easily found in press and on-line [3-5]. Specific examples of two of these demonstrations, "Chemiluminescence" and "Oxidation/Reduction Reaction," are given below.

<u>Chemiluminescence</u> — This demonstration involves the use of a salt solution containing a molecule known as luminol, that gives off a blue light when mixed with a dilute hydrogen peroxide solution. In a dark room, the solutions are mixed in a funnel which is attached to a length of clear tubing and the glowing mixture is circulated through a field of loops and coils by a pump. The light lasts for several minutes.

Prior to the demonstration, the undergraduate student discusses :

- the safety implications (proper handling of all chemicals even in "chemistry sets," safety goggles, etc.);
- chemistry in the "lightning" bug (bioluminescence, chemiluminescence).

After the demonstration, the undergraduate student discusses:

- how it is similar to the "light sticks" that are familiar;
- how the reaction did not go on forever and why;
- what to do with the final product, leading to a discussion of recycling, chemical waste, pollution, etc.

<u>Oxidation/Reduction Reaction</u> — This demonstration involves putting a small amount (about ½ teaspoon) of dishwashing detergent in a graduated cylinder, and (using gloves) adding about 30ml of concentrated hydrogen peroxide (caution: this can burn the skin). Upon the addition of about ½ teaspoon of dry potassium iodide, water and oxygen gas are liberated and the gas makes the detergent foam up and out of the graduated cylinder. Brown specks of iodine are also produced in the foam. The graduated cylinder is placed in a pan to facilitate clean-up.

Prior to the demonstration, the undergraduate student discusses:

- the safety implications of this demonstration and cautions the audience not to try any demonstrations without proper training and supervision;
- the use of a baseball — the demonstrator becomes the "baseball pitcher" and a volunteer as a "baseball catcher," as the demonstrator tosses the baseball to the catcher — to relate these familiar **terms** to "oxidation" and "reduction" with the baseball serving as the electron.

After the demonstration, the undergraduate student discusses:

- was there a reaction? if yes, how can you tell?
- how the iodide ion was converted to iodine and relates this to the iodine solution that is used to disinfect skin;
- how the reaction did not go on forever and why;
- how a battery is also an oxidation/reduction reaction with **an electron** being transferred (and why batteries do not last forever);
- what to do with the final product, etc.

Results

The *Chemistry 100* students' perceptions about science were evaluated with a pre- and post-course questionnaire (Appendix A). The data obtained from this questionnaire were compared to a *CHM 100* section taught by the same instructor without using these demonstrations. However, the "regular non-demonstration" [R] course was given during the fall semester and the "demonstration-based" [D] course was given during the previous summer semester. The results of the pre- and post-course questionnaires for both classes are given in Table 1.

Table 1

Average Responses to Pre- and Post-Course Questionnaire for *Chemistry 100*

		GROUP			
		Regular		Demonstration	
		Pre-	**Post-**	**Pre-**	**Post-**
1	"Chemistry is a boring, hard, and often 'dry' subject."	4.52	3.30	4.21	2.80
2	"My dislike of math makes science hard for me."	3.91	3.80	3.82	3.52
3	"I would consider teaching science or math as a career."	2.33	2.60	2.52	3.51
4	"It is hard to relate science to the 'real world.'"	4.02	3.66	3.76	2.48
5	"Boys are naturally better at science than girls."	1.80	1.80	1.82	1.86

(scale: 5=strongly agree, 4= agree, 3= neutral, 2= disagree, 1= strongly disagree)

The pre-course results for the demonstration based group [D] were similar to that for the "regular" non-demonstration based group [R], indicating that as far as the questionnaire could measure, both groups were initially composed of a similar population of students. The perceptions of chemistry appear to improve in both groups, but the demonstration-based group seemed to become more "excited" about chemistry, as evidenced by the response to question #1 (concerning how boring chemistry is) and question #4 (relating chemistry to the "real world"). Some of the undergraduates were very excited about the demonstrations, especially those given to the younger students in the NSU Children's College. These feelings may be expressed in the different post-course answers in the [R] and [D] groups to question #3, (re: considering teaching as a career). Question #5 (boys versus girls in science) was included as a non-related inquiry to assess the questionnaire. The comments collected from the K-6 students in the NSU Children's College after the demonstrations were overwhelmingly positive. Examples of these comments include: "Science is cool!"; " I want to be a scientist and play with stuff like that"; and simply, "Wow!" Several times the students spontaneously burst into applause after a demonstration.

The undergraduate students in the summer section [R] had higher grades than those in the section held during the academic year [D]; however, this is usually the case for this course at NSU. Based on the distribution of grades earned in these course sections, the use of demonstrations did not seem to have an effect on the ability of the students to understand concepts in chemistry. However on the course evaluation in the [D] section, over one-quarter of the undergraduates commented that the course was more fun than they thought it would be and the demonstrations helped them stay focused. Example comments included: " I dreaded taking chemistry, but this course turned out to be sort of fun"; "I wish I had done this sort of thing in high school"; and, "Thanks for making the subject more interesting by including the demos." No such similar comments were given for the [R] section. Since the number of students in these sections was low (28 and 18 students in the [R] and [D] groups, respectively) and the differences in response to the questions relatively small, the results of this study can only be viewed as pilot data suggesting possible trends. Based on this *limited preliminary study*, demonstrations conducted by the instructor, as well as the student, should be considered for implementation in these courses and further studied as an integral part of the teaching strategy for science courses. Additionally, demonstrations should be evaluated for use in showing undergraduate students that teaching science can be an exciting, rewarding profession. ■

References

[1] A. Hobson," Combating Science Anxiety," *APS News*, **7**(9) (1998).

[2] J.A. Craven and J. Penick, "Preparing New Teachers to Teach Science: The Role of the Science Teacher Educator," *Electronic Journal of Science Education*, **6**(1) (2001).

[3] R. Schriener, B. Shakashiri, E. Scott, J. Bell, and M. Testen, *Chemical Demonstrations*, University of Wisconsin Press, Madison, WI, 1990.

[4] The Department of Chemistry, University College London Website, Internet: http://www.chem.ucl.ac.uk/demonstrations/

[5] *Science is Fun in the Lab of Shakhashiri*, University of Wisconsin-Madison, Internet: http://scifun.chem.wisc.edu/

APPENDIX A

Please express your feelings to the following questions using the scale at right. Circle your answers.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Chemistry is a boring, hard, and often “dry”subject	5	4	3	2	1
2. My dislike of math makes science hard for me	5	4	3	2	1
3. I would consider teaching science or math as a career	5	4	3	2	1
4. It is hard to relate science to the “real world”	5	4	3	2	1
5. Boys are naturally better at science than girls	5	4	3	2	1

INTEGRATION OF TECHNOLOGY IN MATH AND SCIENCE EDUCATION—A MODEL FOR TEACHING ELEMENTARY AND MIDDLE SCHOOL PRE-SERVICE TEACHERS

R.W. FISHER, J.D. HA, and J.P. CHINNICI
Dept. of Biology, Virginia Commonwealth University
Richmond, VA 23284-2012
rwfisher@vcu.edu

Abstract

This paper describes the development and implementation of a course, *Integration of Technology in Math and Science Education*, to introduce elementary and middle school pre-service teachers to real technology skills that they can use in their future classrooms. Activities allowed the students to learn technology skills while using the Internet to enrich their content skills and share information with their fellow students. The course was designed to allow students to master a variety of technology skills, and see how these skills can be used appropriately in their future classrooms, while also increasing their comfort level to use the technology and reduce their resistance and anxiety to use it later in their real-time classrooms. During the class hands-on activities, the students became fluent at using the Internet for enrichment and communication, and at developing strategies for using their new skills to present SOL-relevant lesson plans. Students enter this course with very little in the way of educational technology skills, but leave with a teaching "toolbox" filled with new skills.

Rationale

A course was developed to introduce elementary and middle school pre-service teachers to various new types of classroom technology and show them how to integrate these technologies into their math and science curricula. The importance of such a course is emphasized in the current literature [1-5]. The course, *Integration of Technology in Math and Science Education*, was initially developed with support from the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) in the Spring 2001 semester by the Department of Biology at Virginia Commonwealth University (VCU) in Richmond, Virginia. The course was further developed and modified for the Spring 2002 semester with support from a U.S. Department of Education PT3 grant awarded to the VCU School of Education, with the author as project director.

In today's society, the constant infiltration of advanced technology is no longer a new idea, but more of an expectation [6]. Wireless phones can now double as digital cameras or MP3 players, while nanotechnology is making possible the creation of next-generation computer

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 97 - 103

processors which utilize DNA molecules. E-mail attachments and personal pagers are mere afterthoughts in a world where creativity is the limiting reagent of endless possibilities. One underlying goal of this course was to introduce our elementary and middle school pre-service teachers to the brave new world of technology in the classroom. Most present elementary and many middle school teachers were not math or science majors in college and most elementary pre-service teachers do not major in math or science; of the 32 students that have taken our course, none has been a math or science major. This fact has led us to three major objectives: 1) teach our elementary and middle school pre-service teachers specific technology skills that they can master and apply in their future classrooms; 2) teach them how these technology skills can be used appropriately; and, 3) help increase the comfort level or decrease the anxiety level for using these technologies to help as they bring the wonders of math and science to their students.

Course Design

The first several meetings of the course are used to discuss the research process and to present a good orientation to science, and the critical thinking and problem solving approach. The current educational technology literature emphasizes the importance of these thinking skills [7,8]. Research is defined as an activity of data collection, evaluation, and presentation. We distinguish between descriptive and hypothesis-based research and emphasize that both are needed to add new data to the existing science database. We define both the dependent and independent variables and develop hands-on projects that allow the students to formulate null hypotheses and test for significant differences in the data sets collected. We introduce GraphPad's *InStat* program with which they conduct both descriptive (means, medians, modes) and hypothesis testing (parametric and nonparametric) data analyses.

We also spend time discussing the components of experimental design and the basics of research planning. They learn how to collect data sets carefully and accurately, and record these data in well designed research laboratory notebooks. We emphasize the importance of running experiments in replicate and in repeating runs a number of times before drawing conclusions.

As the course continues, the students are introduced to a variety of web-based tools that can be used to assist them as teachers and enrich their content knowledge (see Appendix A). These activities are centered around *BlackBoard*, a web-based course management software program. The class is divided into small work/task groups of 3-4 students. Students learn how to use e-mail and Internet forums to transfer and share data. They learn how to search the Internet (often using *Google*) for enrichment materials and then share these via the Internet with their group and/or the entire class. These activities introduce the students to the concept of student-centered classrooms with which they can experiment later in their future classrooms [9]. Individual students also learn how to use *BlackBoard* to prepare their own personal web pages and share these with the class. In addition, they learn how to use the Virginia Science Resource Network (VSRN) to contact math, science, and technology experts that have joined the VSRN as mentors.

As student groups start collecting data, they begin to learn how to use *Microsoft Excel* to organize and evaluate their data sets. They also use the *InStat* program for statistical analysis, and learn how to move data between these two programs and out to the *BlackBoard* website. Completed data sets are then graphically formatted using GraphPad's *Prism* program, and prepared for group presentation using Microsoft's *PowerPoint*. As the students complete these activities, they become very skilled with the technology and are ready for more complex experiences.

The remainder of the semester is dedicated to hands-on activities. We start with several simple dataset generation activities involving fruit fly mutation analysis, and lettuce seed germination and seedling growth characteristics. With the fruit fly, they run several hybrid crosses and use chi-square analysis to help identify patterns of appearance of phenotypes. With the lettuce, they collect descriptive data on germination (%) and also calculate average root and hypocotyls growth rates. These data sets are evaluated using the software and protocols learned earlier in the course and then prepared for presentation.

As the semester continues, the student groups work in three-week cycles. During Week 1, they are introduced to a new technology skill. During Week 2, they perfect the skill and use it to collect data. During Week 3, they present their findings to the rest of the class, both via the Internet and also by real-time seminars. A variety of skills are approached using this format in addition to using a number of computer assisted data acquisition probes.

In the beginning of the three-week cycles, the students learn how to run DNA gel electrophoresis equipment and also the Intel Play QX3 Computer Microscope. They then go through a series of activities using PASCO data acquisition probes including PASCO's hand-held device called the "Xplorer." The Xplorer can be used to collect data at remote sites and it can then be downloaded later to a computer for analysis and presentation. After working with the Xplorer, they learn how to use a variety of PASCO probes including probes for temperature, pH, sound, heart rate, motion, light sensor, and voltage. In the final weeks of the course, they use several probes in combination, such as the temperature probe with the pH probe to look for temperature changes during titration experiments, or the voltage probe with the light sensor to see the relationship between voltage and the amount of light generated from a filament. These activities not only introduce them to new technology, but with Internet enrichment searches, allow them to expand their content learning.

Group Product Outputs

With each three-week cycle, each group of students reinforces their data acquisition, evaluation, and presentation skills and becomes more comfortable with the process. Groups are monitored carefully to make sure all students are appropriately engaged in the activities. During the second week of the cycle involving probeware, the groups are free to design their own specific experiments.

During their presentations during Week 3, they have to present three basic components:

- list some very good interactive websites that could enrich their activity;
- develop strategies for using their technology to introduce specific Virginia Standards of Learning (SOL) for math, science and/or technology;
- describe in detail specific relevant lesson plans that they could use in their future classrooms.

Students found some really good sites including: one on writing reports (www.ncsu.edu/labwrite); one for enrichment (http://sciencespot.net/Pages/kdzbio.html); and, one for self-training (www.freeskills.com). In addition to the third week requirements for each cycle, the students have two additional final product requirements: 1) a detailed three-ring binder filled with descriptions of all their activities, websites, SOL links, lesson plans, and notes which they take with them; and, 2) a final Grand Symposium production. During the Grand Symposium, they invite faculty and other persons from all of the math and science departments at VCU, in addition to interested faculty from the VCU School of Education, to come for an afternoon of sharing. Each group prepares several hands-on activities and shares them with the symposium visitors.

With each activity, we discuss how the various technologies they learn could be integrated into their math and science lesson plans. We also discuss how the math and science lesson plans themselves could be integrated and effectively presented to their future elementary and middle school students.

Conclusion — Impact on Students

Students were continually monitored throughout the course. Informal group and individual interviews were conducted by Fisher and Ha. The overall goal of the course was to introduce the students to a variety of technology-based skills and help them discover how these new tools could be integrated into their math and science curricula. Students were assessed, by interview, during the first class meeting to determine skill and comfort levels for using basic classroom technologies in the areas of electronic media: e-mail, Internet, forums, web pages, *BlackBoard*, *Google*, and the VSRN. They were also assessed in the area of computer-based data acquisition and data presentation protocols including: *Microsoft Word*, *Excel*, and *PowerPoint*; *Instat* and *Prism*; computer-based probeware, such as those developed by PASCO; and, the PC QX3 microscope. They were also asked if they were familiar with any of the new DNA technologies, such as DNA gel electrophoresis.

The results from these initial interviews were somewhat surprising, but maybe not unexpected in a group of mainly non-math and science majors. Basically, the students had little or no skills in the above listed areas. Some had basic skills with the Internet, e-mail and *Microsoft Word* and a little exposure to *Excel*, but no real exposure to the other skills we planned to cover.

Similar assessments were made as the semester progressed and new skills were introduced. At the end of the semester, students were interviewed to collect information on exit attitudes. All students reported increases in their technology skills in all the areas presented. In addition, most students felt much more comfortable with these new skills and felt ready to use them in their future classrooms. We conclude that our approach works and could be tried with other groups of future teachers who are not math or science majors.

Acknowledgments

We wish to thank both the VCEPT and PT3 programs for their support, and also all the VCU faculty that supported our students by attending the Grand Symposia. ■

References

[1] G.J. Anglin, *Instructional Technology: Past, Present, and Future*, Libraries Unlimited, Englewood, CO, 1995.

[2] K. Fulton, "Learning in a Digital Age: Insights into the Issues—The Skills Students Need for Technological Fluency," *T.H.E. Journal,* **25**(7) (1998) 60-63.

[3] B. Means and K. Olson, "The Link Between Technology and Authentic Learning," *Educational Leadership,* **51**(7) (1994) 15-18.

[4] K.L. Peck and D. Dorricott, "Why Use Technology?" *Educational Leadership,* **51**(7) (1994) 11-13.

[5] R.W. Riley, *Getting America's Students Ready for the 21st Century—Meeting the Technology Literacy Challenge: A Report to the Nation on Technology and Education*, US Department of Education, Washington, DC, 1996.

[6] *Educating Teachers of Science, Mathematics, and Technology—New Practices for the New Millennium*, National Research Council, Washington, DC, 2001.

[7] D.H. Jonassen, *Computers in the Classroom: Mindtools for Critical Thinking*, Merrill, Englewood Cliffs, NJ, 1996.

[8] K. Littleton and P. Light (eds.), *Learning with Computers: Analysing Productive Interaction*, Routledge, London and New York, 1999.

[9] J.H. Sandholtz, C. Ringstaff, and D. Dwyer, *Teaching with Technology: Creating Student-Centered Classrooms*, Teachers College Press, New York, NY, 1997.

APPENDIX A

Blackboard: a course management software program — http://blackboard.com/

Free Skills: free online tutorials for a variety of software — http://www.freeskills.com/

Google: a great search engine — http://www.google.com/

GraphPad: a site to download simple to use statistics and graphics programs — http://www.graphpad.com/welcome.htm

Intel's QX3 microscope: very nice learning site for the QX3 microscope — http://micro.magnet.fsu.edu/optics/intelplay/

Lab Write: great site for data logging and evaluation protocols — http://www.ncsu.edu/labwrite/

PASCO: computer probeware company — http://www.pasco.com/

Science Spot: great links for enrichment sites — http://sciencespot.net/Pages/kdzbio.html

Virginia Science Resource Network: a site that can link to expert mentors — http://www.vsrn.org/

MATHEMATICS FOR A NON-SCIENCE MAJORS CHEMISTRY COURSE

D.D. SHILLADY
Dept. of Chemistry, Virginia Commonwealth University
Richmond, Virginia 23284

Abstract

A chemistry course developed for non-science majors has been taught at Virginia Commonwealth University for the past five years. *CHEM 112* uses current event articles from science magazines to make use of a verbal channel of learning in non-science majors, but some mathematics is necessary. Examples are given of successful presentation of nuclear chemistry and data needed for a balanced discussion of global warming. Manipulation of symbols in balancing chemical and nuclear reactions, simple algebra, and logarithms for pH and unit analysis of simple stoichiometric conversions are fundamental to basic chemistry. The population of a voting democracy could benefit from basic education in the concepts of logarithms and algebra in one variable in order to function in a society of increasing dependence on technology.

Introduction

Through the National Science Foundation (NSF) grant that formed the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), several new courses were developed as general education requirements, although students were free to select three from a list of seven or eight such courses in chemistry, physics, and biology. After teaching calculus-based courses in physical chemistry and molecular physics for almost thirty years, it was a new experience to find students preparing for studies in environmental law who were adverse to algebra in one variable. However, we take the position that it is essential that the general population have a working understanding of general principles of science and technology. The course, *CHEM 112: Chemistry in the News*, has attempted to use current events in science to motivate realization of the role of chemistry in our technological society.

It seems obvious that to a large extent students make broad decisions regarding science before choosing an academic major in a college or university. Thus, students in a course for non-science majors may have little interest in science; and yet, our society is increasingly dependent on technology so that science literacy is a component of citizenship. Some students of high ability simply choose majors in non-science fields due to other interests, but a course specifically for non-science majors will likely include students with "math-phobia." *CHEM 112* is designed to use the strengths of students in writing and reading comprehension, but at the same time increase

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 105 - 115

understanding of chemical issues with carefully chosen applications of mathematics.

The structure of *CHEM 112* involves student discussion, computer simulations and traditional lecturing twice a week with a writing component. Each week, a new article is introduced from a magazine, such as *Discover* or *Chemical & Engineering News*, and frequently daily newspaper articles are provided to show current applications. Class discussion is stimulated by the professor posing at least two sides of a question and the students are required to write a one-page summary of the article, including a lead-in copy of the first paragraph of the article with a correct citation of the author and source. The lead paragraph is to stimulate good writing style and in essence the students only need to write two paragraphs of their own. Class discussion is supplemented by demonstrations and computer modeling simulations for certain interesting molecules. The reports are graded for content and grammar on a ten-point scale. Studies are underway to compare the improvement of the assigned papers over the course of a semester in *CHEM 112* both as a reinforcement of writing skills and as a "verbal learning channel"; but at this time, it can only be said that the improvement in the quality of the reports improves rapidly within the first three or four weeks of the semester.

At the midpoint of the course, a double (two page) assignment is given to report on the chemistry and environmental quality of one of the rivers in Virginia that empties into the Chesapeake Bay. Groups of four to six students are given this assignment about six weeks before the end of the class to provide time for research (mostly via the Internet) of a given river. All members of a group are given the same grade for the group report and there is evident enthusiasm for this mode of learning. This study fosters awareness of geography on the regional level and it reinforces the importance of aquatic ecology in terms of drinking water and food sources. Maps of the rivers and the Chesapeake Bay are provided to the groups and this is a lively activity with students sharing and consolidating the information they find. The delicate balance of waste treatment and the need for potable water is made quite evident from this study of specific rivers in Virginia. This study also shows that pH is an essential descriptor of water and brings base ten logarithms into discussion of water quality.

Supplemental assignments are offered to all students outside of class in the use of the *SIM-EARTH* [1] computer game by Maxis. As a 3-credit course without a laboratory component, *CHEM 112* has offered scheduled introductions into the use of *SIM-EARTH* by a talented assistant. Future use without an assistant will use out-of-class assignments with the introduction in several lectures.

This game can be quite sophisticated in showing environmental trends on the planets of Venus, Earth, and Mars. After simulating environmental trends in the atmosphere and oceans of planet Earth, the next game assignment is to try to "terraform" Mars by means available to the program, such as using nuclear heat to release carbon dioxide to warm Mars or somehow bring an ice meteor to crash on Mars to provide water. These assignments are available for extra credit in a laboratory with sixteen personal computers. A whole course could be developed using *SIM-EARTH*, but we choose to spend time on other topics as well. This simulation of planetary geospheres puts emphasis on global warming due to burning fossil fuels which increases atmospheric carbon dioxide. This justifies a demonstration of unit analysis showing how much carbon dioxide is formed for each gallon of gasoline (octane) burned. Even a simple example of chemical stoichiometry is very complex for a non-science major, but the need to obtain the result relative to global warming renders this lecture acceptable to non-science students.

.Another use of PC technology has been found in the use of the modeling program *CHEMSITE* [2] available from CHEMSW. It has been found that if we draw molecules with the program, we can teach chemistry by asking the students to observe simple valence rules. For instance after drawing about ten molecules, a table can be formed in lecture showing that carbon always has four bonds, oxygen has two, nitrogen has three, and hydrogen has one bond. In this way, students visually "discover" common rules of chemical valence. *CHEMSITE* can also be used to show students that molecules are constantly vibrating at room temperature and also that molecules have complex 3-dimensional shapes. Computer programs accessible during the lecture can be used spontaneously to show a point about a chemical compound if the professor has developed skill in the use of the program outside of class.

Minimum Mathematics

A chemistry course without any mathematics restricts the chemistry a great deal. It should be stated that a number of chemistry texts for non-science majors assume that mathematics should be avoided to the greatest possible extent. Some educators openly profess that there should be no mathematics at all in a non-science majors course in chemistry! In a large class, there is a very broad range of ability and skill in the use of basic mathematics so that some students resist the use of any mathematics, while other students may be bored by trivial lecture material. The strength of non-science majors is their reading comprehension and writing ability so the assignment of weekly, one-page reports is a good way to convey chemistry concepts to them via a "verbal channel." However, over the last five years, we have explored ways to introduce some mathematics into non-science majors chemistry and we have considered what are the minimal levels of mathematics that add the most additional meaning to verbal concepts. Some of our findings have been surprising and will be shared here.

pH

First, a key concept in environmental chemistry wherever water is involved is pH, a logarithmic measure of acidity in water. In a study of the Potomac River, it was found that a certain part of the Potomac has a pH as low as 5, acidity comparable to vinegar. Class preparation in the mathematics of pH helped students appreciate the acidity of river water.

$$pH = -\log_{10}\left[H^+\right] \qquad (1)$$

The basic experimental fact is that water dissociates to a slight degree into H^+ and $(OH)^-$ as

$$H_2O \rightarrow H^+ + (OH)^- \text{ and } H^+ + (OH)^- \rightarrow H_2O.$$

This set of rapid reactions cause an important relationship as an equilibrium constant, K_{eq}. For water $K_{eq} = 1.0x10^{-14}$ as the relation

$$[H^+][OH^-] = 1.0x10^{-14}\,. \qquad (2)$$

Thus, $[H^+]$ and $[OH^-]$ are expressed by the special symbol "[ ]" as moles/liter in solution (one mole is $6.0225x10^{23}$) and when $[H^+]=[OH^-]$ they each equal the square root of K_{eq} as $1.0x10^{-7}$ and a pH of 7. When [H+] increases, $[OH^-]$ decreases and equation (2) is maintained, leading to pH lower than 7 for acid solutions. Conversely, the pH is above 7 in a basic solution. Mathematically, it is possible for highly concentrated acids to have a pH below 0 (12 molar HCl) or above 14 (moistened pellets of NaOH), but in a typical aqueous environment the range of pH is from 4 to 10. This material is fundamental to any discussion of chemistry on a planet like Earth on which about 71% of the surface of the planet is covered by water; especially when about 65% of our human bodies are also water. The topic of pH is simply essential to much of chemistry and yet the commonly measured quantity involves logarithms. It is important to also define $pOH = -\log_{10}[OH^-]$ and it can be seen from taking the log of equation (2) that pH + pOH = 14 and that in solutions where $[OH^-]$ is larger than [H+] (a "basic" solution) pH = 14 - pOH. These relationships are trivial in courses for chemistry majors and yet the use of logarithms causes difficulty with the non-science majors.

One way to introduce logarithms is to show that simple concentrations such as $[H^+]=0.001$ from a strong acid such as HCl in water can be written as $0.001 = 1.0\text{x}10^{-3}$ which leads to pH=3 and that the logarithm (base 10) is simply the power of 10. In the case of negative exponents, the definition of pH simply discards the minus sign due to the definition of pH in equation (1). When HCl dissociates in water, the Cl^- merely becomes a "spectator ion"; it is the H^+ ion that causes the acidity. It is important to *slowly* show several examples, such as for 0.1, 0.01, 0.001, 0.0001 etc., but this is sufficient to teach the concept. In a second lecture, the case of numbers in between exact powers of 10, such as $[H^+]=0.05$, can be illustrated using calculators with $\log_{10}$ functions to obtain pH=1.3.

Table 1
pH and pOH of Simple Acids and Bases in Water

Solute	**Concentration (moles/L)**	**pH**	**pOH**	**Common Source**
HCl	0.1	1	13	Stomach Acid
HCl	0.01	2	12	
HCl	0.001 3	11		
HCl	0.0001	4	10	
H_3O^+	0.000063	4.2	9.8	Acid Rain (SO_2)
H_3O^+	0.00001 5	9		Normal Clean Rain
H_2CO_3	0.0000025 5.6	8.4		Carbonated Water
H_2O	55.51(*)	7	7	Pure Water (*)
NaOH	0.0001	10	4	
NaOH	0.001 11	3		
KOH+NaOH	0.01	12	2	Wood Ashes
NaOH	0.1	13	1	

(*) Bulk pure water = (1000g/L / 18.016g/mole)= 55.51 moles/L, but only dissociates slightly so that $[H^+]=[OH^-]=1.0\text{x}10^{-7}$ moles/L

The issue here is to slowly present simple examples with motivation as to the importance of understanding aqueous pH. By using the correct mathematics on a few chosen topics of importance, a more thorough presentation of acid-base chemistry can be presented in spite of student reticence regarding logarithms.

Another topic in which the concept of pH is critical is the definition of acid rain as rainwater with a pH below that of natural clean rain [3] at pH=5.0. One might expect the pH of rain to be about 5.6 due to dissolved carbon dioxide forming the weak acid carbonic acid, H_2CO_3, but worldwide the pH of clean rain is slightly lower. Acid rain can have a pH as low as 4 and typically has a pH of 4.2 to 4.4; almost ten times the [H+] as normal rain (note each unit on a logarithmic scale is a factor of 10). The use of logarithms for discussion of pH is one application of basic mathematics which has sufficient significance as to justify some extra class time spent in going over base 10 logarithms.

Temperature

Temperature scales are another area of chemistry where simple mathematics is applicable. Converting Fahrenheit (F) degrees to Celsius degrees (C) and then to the Kelvin scale of absolute temperature (K) is a trivial example of simple algebra as in equation (3):

$$F = (9/5)C + 32 \text{ and } K = C + 273.15 . \tag{3}$$

It is possible to purchase a single thermometer with both scales written side by side to convince students that the (9/5) ratio is due to 180 degrees F but 100 degrees C for the same physical conditions of ice water and boiling water (at one atmosphere external pressure); (180/100)=(9/5). The physical interval is the same in terms of energy, but arbitrary human scales have resulted in different incremental degrees. It is important to go very slowly in a lecture when showing that the two scales yield the same value at -40 degrees. This is easily done by setting F = C, but the algebra which follows can cause consternation to an English major because ninth grade algebra was the last time that student did such a calculation. We should add that such a student may be brilliant in verbal reasoning and fully prepared to take a course in the tax code in law school, but he/she may have not done algebra for a long time and may have delayed taking a required science course until the senior year of university education! One motivating example is to convert normal human body temperature of 98.6 degrees F to the Centigrade equivalent of 37 degrees C and then show that is about 310.2 Kelvin. Our conclusion from teaching *CHEM 112* for over five years is that university education should not avoid algebra in one variable, but that is about the limit of algebraic complexity to demand from students with primary aptitude in verbal reasoning. There are some students in this class intending to earn a law degree; those students need simple but accurate mathematical treatments of basic chemistry if they plan to specialize in environmental law.

Stoichiometry

After using *SIM-EARTH* simulations and discussing several articles on atmospheric effects of SO_2 leading to acid rain [4] and global warming [5] due to increasing amounts of CO_2, a question arises. How much of these gases are due to natural causes such as volcanos compared to human activities such as burning fossil fuels, some of which contain sulfur which lead to SO_2 as well as CO_2?

$$SO_2 + H_2O \text{->} H_2SO_3 \; ; \quad 2\,H_2SO_3 + O_2 \text{->} 2\,H_2SO_4$$

Quantitative use of balanced chemical reactions to calculate mass of reactants consumed and products produced is called stoichiometry. Here we use it to bring factual information to a controversial political question. We can gain insight to the issue of human responsibility for global warming by calculating the pounds of CO_2 formed from one gallon of octane (C_8H_{18}) hydrocarbon, the principle component of gasoline. It is also important to note that in physical science, many numerical values also carry units.

$$1\,C_8H_{18} + (25/2)\,O_2 \rightarrow 8\,CO_2 + 9\,H_2O \tag{4}$$

CHEMSITE molecular modeling can be used in the lecture to show the structure of several isomeric forms of C_8H_{18}, such as the linear form of n-octane or the branched form used as the standard of octane rating for internal combustion engines, 2,2,4-trimethylpentane and there are other isomers. The linear octane has a density [6] of 0.7028 grams/ml at 20 degrees C and the branched isomer has a density [6] of 0.69194 grams/ml at 20 degrees C. Since there is a mixture of isomers in gasoline, we will use a value of 0.70 grams/cc. We can also use the atomic weights of C=12.011, H=1.00794, and O=15.9994 grams/mole with the molecular formulas to get the gram molecular weights of the compounds per mole. For instance, the gram molecular weight of CO_2 is the sum of one C (12.011) and two O (15.9994) = 44.0098 grams/mole. Similar calculation yields a gram molecular weight of 114.23092 for C_8H_{18} (the answer will be rounded to two significant figures at the end of the calculation due to the use of 0.70 for the density). Thus using units:

$$\frac{(1\,gal.)(4\,qt/gal.)(946\,ml/qt)(0.70\,g/ml)}{(114.23092\,g/mole\,C_8H_{18}} = 23.1881\,moles\,C_8H_{18}$$

This means that one gallon of octane equals 23.1881 moles of octane. From the balanced chemical reaction in (4), there are eight moles of CO_2 produced for every one mole of C_8H_{18} consumed.

$$\frac{(23.1881\,\text{moles}\,C_8H_{18})(8\,\text{moles}\,CO_2/\text{mole}\,C_8H_{18})(44.0098\,\text{g/mole}\,CO_2)}{453.6\,\text{g/pound})} = 17.9983\,\text{pounds}\,CO_2$$

Rounding to two significant figures yields an easily remembered fact that one U.S. gallon of octane will produce eighteen pounds of CO_2 when burned (in an engine or by any other means) and ten gallons of gasoline will produce 180 pounds of carbon dioxide when burned. Using real units adds to the credibility of the result. Note that every quart oil container has 946 ml or 946 cc written on it and that one pound equals 453.6 grams. Such simple factors as 1 quart = 0.946 liters and 1 pound = 0.4536 kilograms should be helpful in dealing with metric units throughout our society.

Nuclear Reactions

There is one surprise from our experience in *CHEM 112*. When *CHEM 112* was organized, a text [7] was developed based on modernizing a soft cover study guide, *General Chemistry*, by George and Richard Sasin and written at Drexel University in 1958. The text was brought up to date by adding several new chapters and some fifteen magazine articles were inserted near related chemistry sections. The Sasin text includes a short chapter on nuclear reactions. After discussion of simple elementary particles, such as protons, electrons, neutrons and positrons, the class was assigned to read about nuclear power as an energy source [8]. The Sasin Chapter 52 is only three pages, but it gives examples for nuclear reactions which can occur in accelerator beams as well as nuclear decay. For instance:

Alpha-particle (${}_2He^4$) Bombardment with Proton emission

$$ {}_{13}Al^{27} + {}_2He^4 \rightarrow {}_{14}Si^{30} + {}_1H^1 \tag{5} $$

Alpha-particle (${}_2He^4$) Bombardment with Neutron emission

$$ {}_5B^{11} + {}_2He^4 \rightarrow {}_7N^{14} + {}_0n^1 \tag{6} $$

Proton Bombardment (${}_1H^1$)

$$ {}_3Li^7 + {}_1H^1 \rightarrow {}_2He^4 + {}_2He^4 \tag{7} $$

Deuteron Bombardment (${}_1D_2 = {}_1H_2$)

$$ {}_3Li^7 + {}_1D^2 \rightarrow {}_4Be^8 + {}_0n^1 \tag{8} $$

Neutron Bombardment ($_0n^1$)

$$_{14}Si^{28} + {}_0n^1 \rightarrow {}_{13}Al^{28} + {}_1H^1 \tag{9}$$

Here we use the convention

$$\left({}_{\text{number of protons}}\text{Element}^{\text{sum of protons and neutrons}} \right)$$

for each isotope. The main point here is that the non-science students seemed to be more interested in this topic than others and they quickly became adept at balancing the number of neutrons and protons on both sides of the nuclear reaction. The class was then able to easily appreciate one typical chain reaction of a nuclear fission reactor as in (10) where just one neutron splits $_{92}U^{235}$ and releases nine neutrons which can cause further reactions. Many other examples were discussed regarding nuclear energy processes.

$$_{98}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{139} + {}_{36}Kr^{88} + 9\ {}_0n^1 + \text{energy} \tag{10}$$

Equation (10) is only one of a number of possible nuclear fission reactions in which neutrons are produced to accelerate the reaction and class discussion was held on the use of Cd rods, C graphite and heavy water (D_2O) to slow the neutrons for control of the reaction.

In reviewing the student interest in nuclear reactions, it is noted that students generally are concerned about nuclear weapons and nuclear waste disposal from reactors. They are also concerned about global politics based on petroleum energy sources. That is, the topic itself is of concern and interest to non-science students. We report here that students are able to consider such a politically important topic in science and not be encumbered by any mathematics more than adding and subtracting integers and simply balancing the total number of protons and neutrons on each side of a nuclear reaction. While this may seem trivial, the topic itself is so important that it is worth pointing out that nuclear reactions can be treated in a non-science majors class more effectively than might be supposed given the aura of difficulty commonly associated with nuclear physics.

Conclusion

Teaching rudiments of chemistry to non-science majors is very important to improving science literacy in a society that is increasingly dependent on technology. Chemistry is a "central science" and chemical literacy in the general population is an important component of political judgment. Our position is that the mathematics must not be neglected, and that carefully chosen portions of mathematics can be taught with motivation to solve chemical problems. Minimal mathematics includes base 10 logarithms for use with pH, simple algebra in one variable for temperature conversions, use of common conversions between metric and British units in quantitative calculations and balancing reactions for both chemical and nuclear processes. Observations based on teaching non-science majors for five years and developing a text [7] for their use indicate that they have much greater skills and abilities in writing and reading comprehension than in mathematics. However, it is our position that some limited mathematics must be used to make chemistry meaningful at a level useful to the general population in order to make judgments regarding political questions with a component of technology.

Summarizing positive outcomes from *CHEM 112*, we note especially the already established verbal ability of non-science students to *stimulate critical thinking* regarding science and technology in our society. Use of mathematical concepts (emphasized here) was no more than 15% of *CHEM 112*. Readings explored the lives of Albert Einstein and Madame Curie as well as some recent controversies in the chemistry of Gallium. The students learned from reading selected articles that scientists are humans, but that they try to use quantitative relationships to understand nature. The class discussions bring out student experiences. One profound discussion produced accounts from a student who had worked in Africa in AIDS education following a class-assigned reading on the AIDS virus. Discussion of nuclear power brought renewed interest in two nearby nuclear power plants, and a very interesting discussion followed reading the history of Love Canal in New York and kepone pesticide contamination of the James River in the 1970s which led to a long fishing ban on the James. Discussing articles regarding the tragic history of Easter Island and mudslides in Haiti, both probably caused by unwise depletion of trees, and the controversy of causes and effects of global warming favored environmental concerns. However, there was contrasting analysis of the economic impact of the Kyoto treaty on the U.S. as out of proportion to the effect on China and India.

It should be clear that students in *CHEM 112* learned about some of the global implications of natural and manmade chemistry. Some chemistry majors also took *CHEM 112* as an elective and were enthusiastic about "seeing the big picture" after focusing on specific molecules in other courses. Our recommendation is that carefully motivated use of mathematics brings the full quantitative nature of chemistry to bear on political questions regarding technology and should not be avoided. ■

References

[1] *SIM EARTH The Living Planet*, Maxis, Planet Micro, London, Ont., Internet: http://www.planetmicro.com/

[2] *CHEMSITE, Interactive 3-D Molecular Modeling*, CHEMSW, N. Fairfield, CA, Internet: http://www.chemsw.com/

[3] M. Freemantle, "The Acid Test for Europe," *Chemical and Engineering News*, **73**(18) (1995).

[4] R. Dagani, "Structure of Acid Rain Complex Determined," *Chemical and Engineering News*, **73**(3) (1995).

[5] B. Hileman, "Climate Observations Substantiate Global Warming Models," *Chemical and Engineering News*, **73**(48) (1995).

[6] S. Budavari (ed.), *Merck Index, 12th Ed.*, Merck and Co., Inc., Whitehouse Station, NJ, 1996.

[7] D. Shillady, R. Sasin, M. Hobbs, and G. Wynek, *Chemical Materials in the News*, VCU Press, Richmond, VA, 1999.

[8] B. Hileman, "Hard Choices for Nuclear Energy," *Chemical and Engineering News*, **74**(44) (1996).

THE IMPACT OF A CLINICAL FACULTY INSTITUTE ON PARTICIPANTS' SKILLS FOR MENTORING NOVICE TEACHERS, GRADES K-8

J.H. COTHRON
Mathematics & Science Center, Richmond, VA 23223
G.M. BASS, JR.
School of Education, College of William and Mary
Williamsburg, VA 23187
gmbass@wm.edu

Abstract

A seven-day Clinical Faculty Institute was implemented to increase the skills of mentor teachers and to develop a cadre of Clinical Faculty for the four participating colleges and universities. The 128 participants entered with "some confidence" in their ability to mentor novice teachers in areas typically taught in methods courses; whereas, they displayed "minimal confidence" in skills typically taught in supervisory courses. By the end of the Institute, participants showed significant changes in their "self-perceptions" of skills in twenty areas, with post-scores clustering between 3.5 and 3.9 on a four-point scale. Future institutes should focus on supervisory skills and then emphasize more reflection upon the congruence of teaching, with the "best practices" articulated in national standards.

Introduction

Over 1,000 future teachers of grades K-8 are educated by four institutions in the Commonwealth of Virginia: Longwood University, Mary Washington College, Norfolk State University, and Virginia Commonwealth University. Data collected by these institutions in 1995 revealed that about 25% of novice teachers' experiences were in the areas of mathematics and science. For this reason, the institutions sought to establish a Clinical Faculty Institute for mentors of K-8 teachers and a cadre of Clinical Faculty members at each institution. With funding from the NSF-funded Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), an institute was developed and implemented to increase Clinical Faculty members' skills in:

- establishing collaborative and collegial relationships between K-8 and university faculty;
- coaching and mentoring novice teachers; practicum students, student teachers, and beginning teachers;
- understanding best practices in mathematics and science instruction and articulating these practices.

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 117 - 132

The purpose of this article is to describe the Clinical Faculty Institute and its impact on the participants.

Characteristics, Expectations, and Selection of Clinical Faculty

In the fall of 1997, a Clinical Faculty Committee was established to provide guidance for program development and implementation. The committee consisted of representatives from the Mathematics & Science Center and from each of the four institutions, including one or two administrators (typically deans), one or two teacher educators, and several K-8 educators associated with the institution. The Clinical Faculty Committee established an operational definition of a Clinical Faculty member, articulated expectations, and developed a timeline and process for selecting K-8 educators to participate in a Collaborative-wide residential institute held at the Mathematics & Science Center in Richmond, Virginia.

Operational Definition — Clinical Faculty members were defined as a "cooperating teacher plus," that is, one who had demonstrated excellence in the teaching of mathematics and science, received professional recognition, possessed coaching and mentoring skills, understood "best practices" in the teaching of math and science, and could articulate "best practices" to novice teachers. In addition, a Clinical Faculty member had to be recommended by the school division or institution of higher education, selected by the college or university, and approved by the school division.

Expectations — Generally, Clinical Faculty members were to perform the duties of a cooperating teacher, including supervision of practicum and student teachers. In addition, Clinical Faculty members were expected to co-teach academic or methods courses at the college or university, communicate the college or university program to novice teachers and fellow professionals, advise the college or university on development of courses and in-school experiences for novice teachers, model exemplary classroom lessons (math and science) for novice teachers and peers, and provide general leadership for cooperating teachers within a school. With more experience, Clinical Faculty staff were also expected to become a "trainer of trainers" by working as a member of a team to design and implement Clinical Faculty institutes and workshops at the local level.

Criteria for Selection — On the Clinical Faculty application, applicants provided demographic information, educational background including degrees earned and major, synopsis of full-time teaching experience, work with pre-service teachers, and professional involvement and leadership. In addition, applicants responded to four short questions, using a maximum of one page, about commitment to the overall project, knowledge of math and science standards, examples of exemplary practices implemented, and self-perceptions of his/her role as a mentor. Each college or university selected the participants for the Clinical Faculty Institute based upon the following criteria: evidence of continued learning with a master's degree preferred, a minimum of five years of teaching experience, prior experience working with novice teachers in a school setting, demonstrated ability to implement exemplary instruction in math and science, strong oral and written communication skills, effective human relations skills, demonstrated ability to work with adults, evidence of professional involvement, and commitment to the overall project and mentoring of fellow professionals.

Timeline — During the fall and winter, each institution advertised for participants for a Clinical Faculty Institute, to be held the following summer. The general timeline included notifying key personnel within K-12 school divisions (September and October), conducting awareness sessions for potential applicants (November and December), distributing and receiving applications (January and February), and selecting participants (March). Applications were then forwarded to the Mathematics & Science Center for inclusion in the Clinical Faculty Summer Institute. In April and May, the Center contacted applicants, surveyed participants about areas in which more math and science training were desired, and customized the general seminar agenda to meet participants' needs.

Population — During three summers, from 1997 to 1999, a total of 128 Clinical Faculty were trained at the Collaborative-wide institutes held at the Mathematics & Science Center. Overall, the population consisted of 94 elementary teachers, 23 middle school teachers, 1 special education teacher, and 10 teachers for whom demographic information is unavailable. As shown in Table 1, teaching experience ranged from 1 to 37 years, with the typical participant having 14.6 years of experience. Typically, participants had similar experience in teaching science (11.79 years) and math (12.81 years). Overall, the participants had been in a school division for multiple years, with the average being 12.07 years.

Table 1
Teaching Experience of Participants

Category	Mean (yrs)	Standard Deviation (yrs)	Range (yrs)
Total years of professional teaching experience	14.60	8.63	1 – 37
Years of experience teaching math	12.81	8.21	1 – 31
Years of experience teaching science	11.79	8.27	1 – 37
Number of years in current school system	12.07	8.07	1 – 37

Methods and Materials

Leadership for development and implementation of the Collaborative-wide institute was provided by Mary Washington College (MWC) and the Mathematics & Science Center, a unique consortium of seven K-12 school divisions that is located in Richmond, Virginia. MWC was selected because it had a successful Clinical Faculty Program, although it did not focus specifically on math and science. The Mathematics & Science Center was selected because of its subject-matter expertise and proven track record of developing effective professional development programs for K-12 educators.

The Clinical Faculty Institute consisted of a one-week institute during the summer and two follow-up sessions during the academic year. Typically, summer sessions were held from 8:30 a.m. to 4:00 p.m. and Saturday academic year follow-up sessions from 8:00 a.m. to 3:30 p.m. All sessions were held at the Mathematics & Science Center. Appropriate breaks and lunches were provided. All participants received daily honoraria, lodging and meals, and mileage to and from the Institute.

Although slight variations occurred during the three summer institutes, approximately 41 hours of instruction were provided annually. Participants received a notebook with written handouts for each session. In addition, *Supervising Student Teachers: The Professional Way* (5^{th} ed.) by Henry and Beasley was used as a supplemental text [1]. For the 1999 Clinical Faculty Institute, the session topics and times are provided in Table 2.

Table 2
Overview of Clinical Faculty Institute

Day	Topic	Time (hrs)
1	Overview of Institute & Pre-Evaluation	0.50
	Needs of Novice Teachers & Role of Clinical Faculty	3.00
	Guiding Novice Teachers to Observe Effective Teaching Behaviors	2.50
2	Introduction & Follow-Up to Prior Day	0.25
	Guiding Novice Teachers to Observe Components of Instruction	1.75
	Concurrent Session A: Math & Science Lessons	1.50
	Guiding Novice Teachers to Implement Activities & Investigations	1.25
	Concurrent Session B: Math & Science Lessons	1.25
3	Introduction & Follow-Up to Prior Day	0.25
	Guiding Novice Teachers: From Observation to Problem-Solving Conferences	5.75
4	Introduction & Follow-Up to Prior Day	0.25
	Guiding Novice Teachers to Meet Academic Standards for All Students	4.25
	Concurrent Session C: Math & Science Lessons	1.50
5	Introduction & Follow-Up to Prior Day	0.25
	Typical Challenges of Working with Novice Teachers	3.00
	Descriptions of College & University Teacher Preparation Programs	1.25
	Summer Closure & Post-Summer Institute Evaluation	0.50
6	Evaluating Student Teachers	3.75
	Concurrent Session D: Math & Science Lessons	2.25
7	Legal Implications of Mentoring Novice Teachers	3.50
	Concurrent Session E: Math & Science Lessons	2.00
	Closure & Post-Evaluation	0.50
	Institute Total	41.00

Day 1: Summer Institute — In the session on "Needs of Novice Teachers & Role of Clinical Faculty," participants identified the needs of novice teachers, related the needs of novice teachers to the role of Clinical Faculty, and applied tenets of adult learning to working with novice teachers. The reflective practitioner model was explained and procedures for encouraging reflection, such as dialogue journals, were described and used throughout the institute.

In the second major session, "Guiding Novice Teachers to Observe Effective Teaching Behaviors," participants used various instruments for making systematic observations of various aspects of teaching and learning at predetermined intervals. Observations were made of various math and science mini-lessons, typically twenty to thirty minutes in length. Then, participants described general competencies of effective teachers. Appropriate uses of instruments with novice teachers at various stages of their preparation were discussed.

Day 2: Summer Institute — The day began with a session on "Guiding Novice Teachers to Observe Components of Instruction." Participants learned to script tape lessons, to make behavioral statements, and to formulate judgment statements using a set of standards. Observations were made of various math and science lessons that focused on explanations and demonstrations. Participants used standards for effective explanations and demonstrations as the basis of judgment statements and strengthened their ability to articulate features of effective instruction.

In the session on "Guiding Novice Teachers to Implement Activities & Investigations," participants completed a self-inventory to determine their use of constructivist and non-constructivist teaching practices, used an instrument to analyze the constructive nature of various instructional strategies, reviewed standards for effective activities and investigations, identified common problems of novice teachers, and discussed challenges that exist when teaching philosophies of university staff, the novice teacher, and the Clinical Faculty member differ substantially.

The "Concurrent Sessions on Math and Science Lessons" were based upon identified needs of participants. Each spring, after institute participants were selected, the Center surveyed participants about components of Virginia's *Standards of Learning* [2] in which more training was needed. At the elementary level, participants identified the earth and physical sciences and the newer mathematical strands, e.g. algebraic thinking, probability/statistics, and geometry. At the middle school level, participants were also interested in the integration of graphing calculators and probes. The math and science concurrent sessions were designed to increase participants' conceptual understanding and/or to share effective instructional strategies.

Day 3: Summer Institute — The entire day was devoted to a session on "Guiding Novice Teachers: From Observations to Problem-Solving Conferences." Through role-playing, participants learned and practiced strategies for observing novice teachers, determining important feedback to communicate, and conducting a daily or weekly conference. Challenges of communicating with defensive teachers were discussed and role-played.

Day 4: Summer Institute — In the session on "Guiding Novice Teachers to Meet Academic Standards for All Students," participants used the principles of "backward design," articulated by Wiggins and McTighe, to help novice teachers turn creative activities into effective standards-based lessons with appropriate assessment [3]. Strategies for using elements of effective instruction to help students design effective lessons based upon a direct, guided inquiry, or inquiry model, were discussed and used to analyze various math and science lessons. Participants also reviewed the Learning Cycle, a constructivist approach used in the design of many elementary programs, and applied it to the analysis of a unit on wind power. As an extension, participants analyzed the effectiveness of various lessons in meeting individual needs, and discussed techniques for helping novice teachers succeed with diverse learners within a classroom. Concurrent sessions on math and science, using the previously described model, were also held.

Day 5: Summer Institute — In "Typical Challenges of Working with Novice Teachers," participants identified unanswered questions and challenges not previously addressed. Various scenarios from the ancillary textbook, *Supervising Student Teachers the Professional Way* (5^{th} ed.) [1], were discussed. Over lunch and in the session entitled, "Teacher Preparation Programs," Clinical Faculty members and staff from each college or university discussed techniques for building effective collaboration between higher education and Clinical Faculty staff, the general teacher preparation program at the institution, and the various in-school experiences required of novice teachers.

Day 6: Academic Year Follow-Up — The first academic year follow-up, typically held in late November or early December, began with a session on "Evaluating Student Teachers." Participants discussed procedures and instruments used to evaluate novice teachers at the participating colleges and universities, and practiced evaluating novice teachers using a checklist, a checklist with narrative, and a narrative. Common challenges encountered with novice teachers during evaluation and tips for handling were discussed. Institute participants led concurrent sessions on math and science.

Day 7: Academic Year Follow-Up — In the second academic year follow-up, typically held in March, the major focus was a session on "Legal Implications of Mentoring Novice Teachers." Participants discussed legal aspects of working with novice teachers, legal decisions rendered in various cases analyzed by participants, and the responsibilities of the Clinical Faculty staff when mentoring a novice educator. Institute participants led concurrent math and science sessions.

Instruments Used to Evaluate Clinical Faculty Institute

Data were collected from the participants at the beginning, end of the summer institute, and end of the academic year. To assess outcomes, a four-point Likert Scale was used to determine participants' self-perceptions of their skills in establishing collaborative and collegial relationships (six questions), coaching and mentoring novice teachers (nine questions), and articulating best practices for teaching mathematical and scientific concepts (seven questions). Participants rated their confidence as: (1)"No Confidence," (2) "Minimal Confidence," (3) "Some Confidence," and (4) "Much Confidence." On the survey, questions about the various components were randomly mixed.

In addition, various questions were used for formative assessment throughout the project. For example, participants were asked to provide feedback on their goals for the Institute, their satisfaction with the Institute's presentations, activities, presenters, and facilities, as well as their recommendations for future institutes.

Results

Collaborative and Collegial Relationships — Six questions on the Likert Survey were constructed to detect changes in participants' self-confidence in strengthening collaborative and collegial relationships between K-8 and university faculty. Mean pre-and post-scores were calculated for each question (see Table 3).

On the pre-test, participants' confidence levels ranged from 2.74 to 3.17, with most values being on the borderline of "minimal" to "some confidence." Participants showed the greatest confidence in areas most directly related to daily teaching; that is, identifying needs of novice teachers and competencies of effective teachers. Participants were less confident about their abilities to identify student teaching requirements, apply tenets of adult learning, build collaborative relationships, and function as Clinical Faculty.

By the end of the Institute, participants' confidence levels on the various questions ranged from 3.52 to 3.82 on the four-point scale. Overall, participants were at the high end of "some confidence" and approaching "much confidence." Participants showed the greatest change (.89), and the largest final scores, on the three topics in which they initially displayed the least confidence.

Table 3

Changes in Participants' Self Perceptions of Ability to Establish Collaborative and Collegial Relationships

Question	**Pre-Mean**	**Post-Mean**	**Change Mean**	**Calculated *t***
Identify general "student teaching" requirements of both universities and local school divisions	2.74	3.63	0.89	9.87
Relate major tenets of adult learning to working with novice teachers	2.76	3.52	0.76	10.00
Build effective collaboration between university faculty and Clinical Faculty	2.82	3.71	0.89	11.10
Relate needs of novice teachers to the role of cooperating teachers/clinical faculty	2.91	3.80	0.89	12.30
Identify the needs of novice teachers	3.11	3.82	0.71	11.28
Describe general competencies of effective teachers	3.17	3.77	0.60	10.35

Note: Numbers in sample ranged from 119 to 122. All paired *t*-tests were statistically significant $p \leq .001$.

During the three years of the Institute, the sessions and time devoted to building collaborative and collegial relationships remained consistent. The three-hour session, "Needs of Novice Teachers & Role of Clinical Faculty," was effective in increasing participants' general understanding of their role as mentors, in articulating concerns they hoped to address during the week, and in fostering relationships among participants from diverse locations. Likewise, the three-hour session held on the fifth day, "Typical Challenges of Working with Novice Teachers," provided an opportunity to articulate and discuss new concerns using the scenarios in the Henry & Beasley text.

For many of the participants, the opportunity to meet with representatives from the various institutes on the fifth day of the Institute was invaluable. College/university representatives and their associated Clinical Faculty ate lunch together, and discussed specific requirements of the institution for practicum and novice teachers. This began a relationship that was continued through periodic meetings of Clinical Faculty on the individual campuses.

<u>Coaching and Mentoring Skills</u> — Nine questions on the Likert Survey solicited participants' perceptions of their skills to mentor and coach novice teachers (see Table 4). Initially, participants' self-perceptions ranged from 2.87 to 3.29. By the end of the Institute, participants' scores ranged from 3.65 to 3.82 and reflected strong confidence in their abilities to coach and mentor.

Participants perceived great gains in their ability to use observation techniques including systematic observations with predetermined criteria and script taping. For many, it was the first time they had used such instruments. Because many practicum students appear with the charge to "observe," but no tools, the teachers thought that the observation instruments would be helpful also in focusing these students' attention on effective teaching behaviors. The session on "Guiding Novice Teachers to Observe Effective Teaching Behaviors" (2.5 hrs) remained consistent over the years and was popular, for the teachers rotated role-playing students and observers in various lessons that focused on the chemistry of solutions. This blend of "supervision" and "experiencing math or science lessons" proved to be the most effective way to incorporate math and science lessons into the Institute.

The session on "Guiding Novice Teachers to Observe Components of Instruction" was generally the same over the years with participants learning to script tape by viewing videos of short explanations or demonstrations, typically ten to fifteen minutes. This short session (1.75

Table 4

Changes in Participants' Self Perceptions of Coaching and Mentoring Skills

Question	Pre-Mean	Post-Mean	Change Mean	Calculated t
Use a systematic process for helping novice teachers to observe other professionals	2.87	3.77	0.90	10.50
Use principles of coaching when working with novice teachers	2.88	3.65	0.77	10.65
Conduct effective evaluations of novice teachers	2.89	3.75	0.86	12.81
Conduct effective supervisory conferences with novice teachers	2.93	3.72	0.79	10.52
Work with novice teachers during the reflecting phase of teaching	3.11	3.79	0.68	10.46
Use active listening techniques with novice teachers	3.11	3.70	0.59	8.60
Work with novice teachers to plan differentiated experiences for students	3.27	3.66	0.39	6.31
Work with novice teachers during the interacting phase of teaching	3.27	3.82	0.55	8.63
Work with novice teachers during the planning phase of teaching	3.29	3.78	0.49	9.06

Note: Numbers in sample ranged from 119 to 122. All paired t-tests were statistically significant $p \leq .001$.

hrs) was effective in introducing the technique and having the observer use "best practices," not personal opinion, as a basis for developing feedback. The session on "Guiding Novice Teachers to Implement Activities & Investigations" (1.25 hrs) involved participants discussing challenges that novice teachers face, analyzing case studies, and discussing appropriate feedback. This session was valuable, but needed additional time for participants to script tape these more complex lessons and to develop feedback based upon standards for effective implementation.

Annually, the session on "Guiding Novice Teachers: From Observation to Problem-Solving Conferences" produced the greatest change among the participants. Virtually none of the participants had received prior training in how to prepare for a supervisory conference and to work effectively with individuals exhibiting various defensive behaviors. Likewise, the academic-year sessions on "Evaluating Student Teachers and Legal Implications of Working with Novice Teachers" introduced teachers to information not encountered previously and greatly increased their self-confidence in mentoring teachers.

Consistently, participants stated that the most significant experiences involved using a variety of observation instruments, providing objective feedback, and planning and conducting conferences, ranging from daily to evaluative. These findings reflect the prior educational experiences of classroom teachers, which include multiple courses on curriculum instruction and curriculum, but limited courses on supervision. Participants also cited the applicability of the supervisory skills to team or department leadership and to interactions with students and parents.

<u>Best Practices and Abilities to Articulate</u> — Seven questions on the Likert Survey addressed participants' perceptions of their skills. Five of the questions were new and two were also included under "coaching and mentoring" skills (see Table 5). Generally, participants entered with higher pre-scores in this area, 3.12 to 3.48, than on other areas. The exception was a question on the SCIS learning cycle in which the terminology, SCIS, negatively impacted scores. Given that the teachers were selected for proven ability to "teach math and science," higher entry scores would be expected. By the end of the Institute, however, scores reflected even more confidence, ranging from 3.23 to 3.80.

Table 5
Changes in Participants' Self-Perceptions of Conceptual Understanding of Best Practices and Ability to Articulate

Question	Pre-Mean	Post-Mean	Change Mean	Calculated t
Use the SCIS learning cycles to analyze an instructional unit	1.99	3.23	1.24	12.59
Describe "best practices" in math and science instruction	3.12	3.75	0.63	10.06
Identify, describe, and apply elements of effective instruction to the design of various types of lessons such as direct instruction, guided inquiry, and open-ended inquiry.	3.12	3.72	0.60	7.54
Work with novice teachers to plan differentiated experiences for students (repeat question)	3.27	3.66	0.39	6.31
Work with novice teachers during the planning phase of teaching (repeat question)	3.29	3.78	0.49	9.06
Use a model lesson to increase students' understanding of math and science concepts	3.36	3.82	0.46	7.19
Describe one's own teaching style and philosophy.	3.48	3.80	0.32	5.37

Note: Numbers in sample ranged from 119 to 122. All paired t-tests were statistically significant $p \leq .001$.

The session on "Guiding Novice Teachers to Meet Academic Standards for All Students" was designed to improve participants' skills in helping novice teachers plan instruction that was consistent with national and state standards. In the summer of 1997, participants were very concerned about helping novice teachers use Virginia's *Standards of Learning* (SOL) [2] as the basis of planning, and the workshop activities reflected this need. From 1997 to 1999, major changes occurred in all Virginia school divisions and colleges as high-stakes testing was implemented. Local divisions aligned curricula and involved teachers in multiple workshops on standards; colleges and universities required all student teachers to develop lesson plans based upon the SOL. Instead of general planning, participants requested assistance in helping novice teachers differentiate strategies to meet the needs of diverse students, and the session was modified to meet this need. Regardless of the emphasis, the length of the session on "Academic Standards for All" needs to be increased, for time to apply concepts was insufficient.

The need for concurrent sessions on math and science lessons varied with the experience of the teacher, the size of the school division, and the year of the Institute. In the summer of 1997, participants rated the concurrent sessions very highly, with older teachers (who had not attended school recently) and those from smaller school divisions rating them the highest. By 1999, most teachers were responsible for implementing highly aligned lock-step curricula in their divisions and perceived little need for new lessons. Interestingly, however, the teachers continued to rate the very unique learning experiences based in the Center's designed facilities (such as the aquaria and space station simulator) very highly. Even though they could not reproduce the experience directly in their classroom, they were positive about the opportunity to learn math and science in less traditional ways.

General Institute — Participants were uniformly positive about: the clarity of the Institute's goals, the range of topics and content covered, the variety of instructional methods and examples, the opportunities to interact, and the written materials provided.

Ratings ranged from 3.61 to 3.81 on a four-point scale (3 = agree and 4 = strongly agree). On open-ended questions, however, participants consistently cited the need for a shorter day. The majority found it difficult to concentrate from 8:30 a.m. to 4:00 p.m. despite a generous lunch hour and breaks. Because of the cost of a residential institute, it was difficult to justify shortening the day (and thus lengthening the number of days). With a non-residential program, day length could be modified.

Conclusion

Participation in a seven-day institute significantly increased participants' perceptions of their abilities to establish collaborative and collegial relationships between K-8 and university faculty, coach and mentor novice teachers, and articulate "best practices" in mathematics and science. Participants entered the Institute with "some confidence" in their ability to mentor students in areas typically taught in methods courses, whereas they displayed "minimal confidence" in skills more typically taught in supervisory courses. Change was greatest in the "supervisory" areas and least in the "teaching" areas, with the result being that post-scores clustered between 3.5 and 3.9 on a four-point scale. The Clinical Faculty Institute provided participants with increased skills for working with novice teachers, as well as promoting skills recommended by the Interstate New Teacher Assessment and Support Consortium (INTASC), such as being a reflective practitioner and fostering relationships within the larger educational community [4]. Overall reaction is best summarized by one participant's comment:

> Every teacher who asks to be a cooperating teacher should go through this Institute. I feel very comfortable now with the notion that a student teacher will be in my classroom and will depend on me for the most positive educational experience possible! I look forward to working as a Clinical Faculty member and hope to increase my involvement in pre-service teacher training.

Based upon the three years of experience in implementing a Clinical Faculty Institute and the results of the Likert Survey and open-ended questions, the authors recommend the following:

- use the operational definition and expectations developed for Clinical Faculty, as well as the timeline, application, and criteria for selection;
- focus the majority of institute time on topics related to supervisory rather than teaching skills;
- utilize some of the time spent on math and science lessons to increase the time spent on academic standards for all students and on additional practice time for participants to observe activities and investigations with various tools, especially script taping;
- deliver math and science content through lessons in which participants rotate role-playing "students" and "observers"—thus, emphasizing ability to identify and articulate best practices rather than acquisition of model lessons;
- if funds permit, continue a seven-day residential institute. If not, reduce costs by holding non-residential institutes and by spreading sessions between the summer and academic year.

Products and Next Steps

Interested educators may obtain a draft copy of the professional development manual, *Clinical Faculty: Resources for Mentoring Novice Teachers of Math and Science*, from the Mathematics & Science Center [5]. The manual includes the instructional materials, evaluation instruments, and administrative tools used to implement the Institute. Currently, classroom data are being collected on the effectiveness of the Clinical Faculty program in "increasing the quality and quantity of math and science instructional experiences engaged in by novice teachers."

Acknowledgements

The Clinical Faculty Institute was developed and implemented by: Julia H. Cothron, Executive Director, Mathematics & Science Center (Institute leader); Sandra White, Associate Professor, Mary Washington College (Institute leader); Courtney Hunter, K-5 Educator, Mathematics & Science Center; Howard Garner, Professor Emeritus, Virginia Commonwealth University; Venitta McCall, Associate Professor, Mary Washington College; and, Linda Sholander, Clinical Faculty, Mary Washington College.

The external evaluator for the Institute was George Bass, Professor, College of William and Mary. ■

References

[1] M.A. Henry and W.W. Beasley, *Supervising Student Teachers: The Professional Way*, Sycamore Press, Terre Haute, IN, 1996.

[2] *Standards for Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

[3] G. Wiggins, and J. McTighe, *Understanding by Design*, Association for Supervision and Curriculum Development, Alexandria, VA, 1999.

[4] *Interstate New Teacher Assessment and Support Consortium*, Council of Chief State School Officers, Washington, DC, Internet: http://www.ccsso.org/instasc.html

[5] J.H. Cothron (ed.), *Clinical Faculty: Resources for Mentoring Novice Teachers of Math and Science*, Mathematics and Science Center, Richmond, VA, (draft manuscript, 2001).

USING TECHNOLOGY WITHIN THE TEACHER PREPARATION PROGRAM AS A MODEL FOR EFFECTIVE INSTRUCTION

J.P. JOHNSON
L.E. WILKOWSKI
Div. of Teacher Education, Virginia Commonwealth University
Richmond, VA 23284
Jpjohnson@vcu.edu
lrhea@richmond.k12.va.us

Abstract

This article describes a methods course for teachers of elementary science and how it was enhanced to increase students' abilities and attitudes toward using technology as a tool in teaching science. The course was enhanced as a result of the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) project. Prior to this project, the course was known for its constructivist approach, cooperative group activities, and experiential base that allowed students to actually do and teach elementary science. As a result of VCEPT, the class now also features an elaborate technology component. Technology of many types are regularly modeled in the methods classroom. Students are exposed to and have hands-on experiences with selected technologies and are asked to use technology in order to complete a variety of different projects.

Introduction

TEDU 517: Methods of Elementary Science, is a three-credit, one-semester course required of all elementary education majors at Virginia Commonwealth University (VCU). The course is designed to present best practices for effective teaching of science. Though not designed to be a content course, much of the content needed by elementary education majors is reviewed through the types of activities presented by its instructors.

The course is designed to be an effective model of a constructivist classroom, one in which students construct or reconstruct their own meaning for concepts through guided inquiry. Therefore, students complete many hands-on activities while working in cooperative groups. These activities require students to utilize basic process skills, such as making observations and measurements, as well as to use scientific reasoning to answer questions through making hypotheses, testing, and formulating inferences and conclusions from the results. While actually using the processes of scientific investigation, pre-service teachers learn how to effectively teach these skills to elementary students.

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 133 – 144

Because of the fact that VCU is located within an urban environment, an emphasis is placed on incorporating strategies to help students adjust to the variety of situations and needs of the students they will encounter. For example, one of the classes deals with working in cooperative groups and typical problems encountered by teachers in an urban classroom.

Rationale for a Strong Technology Component

Today's students are growing up in a world where television is used to stay abreast of current events, discover faraway lands, entertain, and sometimes baby-sit. Many students have home computers or have used computers by the time they have reached school age. Within public schools, computers, televisions, overhead projectors, and laser disk players are but a few examples of equipment that has become standard issue. Computers and related technologies are an integral part of the world today. To fail to integrate technology into the curriculum would be a failure to include a rapidly increasing tool in today's society.

The use of technology within the science course grew out of this observation, as well as from Virginia state requirements that require teachers to have mastered specific technology skills. Students at VCU prove their technological proficiency by taking a competency exam and by completing the teacher prep program that integrates many of the state standards through required projects within the courses.

The teacher preparation program at VCU views technology as doing more than simply meeting state requirements. In monthly School of Education meetings and often in division meetings, there is a regular feature in which a member of the faculty shares with colleagues a way in which technology is being incorporated into his or her class and students' responses to this technology. Faculty here have become excited about students' positive reactions. The positive effects of using technology are borne out in research as well. The Office of Educational Research and Improvement within the U.S. Department of Education conducted a study entitled, *Technology and Education Reform* in which they found the following positive effects of the use of technology [1].

<u>Students tended to play a more active role in their own learning</u> — Traditionally, teachers have had a direct role in dispensing information to students whose role it was to receive it and process it. When students use technology, "The student is actively making choices about how to generate, obtain, manipulate, or display information. Technology use allows many more students

to be actively thinking about information, making choices, and executing skills than is typical in teacher-led lessons. Moreover, when technology is used as a tool to support students in performing authentic tasks, the students are in the position of defining their goals, making design decisions, and evaluating their progress."

Teachers reported an increase in student confidence — Almost all teachers within the study reported an increase in students' self-esteem and motivation. Even within the authors' own experiences, stories can be recounted of students who had difficulty in writing and presenting information in traditional manners, but who would shine when asked to present information using technology. Students also see the relevance of learning to use technology since our society places such value on its use, and examples of its use by adults are readily available.

Students became more adept at tackling difficult assignments — "Teachers for the observed classes and activities at the case study sites were nearly unanimous also in reporting that students were able to handle more complex assignments and do more with higher-order skills because of the supports and capabilities provided by technology."

Increased interactions occurred — For a variety of reasons, increased group work and peer tutoring resulted from the use of technology. Technology also allowed students to interact with resources, experts, and places they could not otherwise access.

In an article entitled, "Technology in the Schools: It *Does* Make a Difference!" author Glori Chaika cited examples of districts that had used technology to get some incredible results [2]. Among her citations are the following studies:

> School officials in West Virginia selected software carefully and then integrated it into the curriculum. They provided students an adequate number of computers, and they thoroughly trained teachers in how to use the software to improve student learning. As a result, student scores on both state tests and the National Assessment of Educational Progress (NAEP) improved. Intriguingly, the study also found that West Virginia's program was more cost-effective than hiring more teachers or reducing class sizes!

A "Report on the Effectiveness of Technology in Education, 1990-1997," conducted by the Software Publishers Association, cites the results of a Vanderbilt University research group's study of at-risk, inner-city kindergartners. The researchers found that students studying language arts in a multimedia environment gained more auditory, language, decoding-in-context, and story-composition skills than did students in a control group who did not use computers.

An Educational Testing Service study discovered that math teachers who used computers could significantly boost fourth and eighth graders' standardized math scores, and a study of 53 elementary, middle, and high schools found that providing cutting-edge technology improves teachers' morale. That ETS study also found that students' attitudes, motivation, and behaviors improved very quickly when they used computers in school.

Changes to the Class

As a result of such research, state technology teacher competencies, an increased interest among faculty, and through funds and support made available through VCEPT, it was decided several years ago that the elementary science methods course would be improved through an emphasis on the use of technology. For these same reasons, the teacher education faculty at VCU became involved in the Virginia Educational Technology Alliance (VETA). Through VETA and VCEPT, we began to meet with other colleges and universities to share the uses of technology within our own classes.

Redesign of the actual methods of a science classroom was done to allow instructors to use technology within the classroom setting. The classroom was equipped with a ceiling-mounted video projector and audio/visual jacks into which a laptop computer and VCR may be plugged. The room was also fitted with two Internet connections.

The curriculum design of the class was altered to incorporate technology through modeling. In utilizing hands-on experiences with the various technologies in the classroom and requiring technology as a tool for student assignments, the knowledge base was effectively expanded, both in technology and in content. Instructors modeled *PowerPoint* by using it to deliver lecture content to the class; *Excel* was used to collect and display data from class experiments; *Inspiration* software created class handouts. The use of concept mapping, a way to help students connect concepts and ideas through visual graphic organizers, was a teaching tool already in place. However, we combined it with *Inspiration* in order to broaden its benefits. This software allows students to create concept maps quickly and easily, and to convert them to outlined notes or vice versa. What especially appealed to both students and instructors about this program was its ease of use.

Interactive video and software were also explored in the class setting. The authors of this work have attended the National Teacher Training Institute which conducts teacher training in how to use video effectively. It was decided to use instructional television to show teachers how to use video interactively. Video has often been a tool that allowed teachers to present information while getting a little grading or other work done at the same time. This form of video presentation requires students and teachers to take a more active role in viewing as the teacher instructs students to watch for answers to particular questions, and stops the video at various times to discuss and test ideas within the video through hands-on activities. Through these modifications, many more styles of learning can be reached and students become much more active learners.

Students were given several projects and assignments that revolve around using technology. They were asked to review websites appropriate for classroom use. Students used the Internet to explore the use of virtual field trips, research, find lesson plans, and use interactive websites; to post notes, interact with pre-service teachers, pose questions, and post lesson plans and announcements on a class website. They were asked to preview instructional software. They used *Excel* spreadsheets during group experiments. They typed assignments using word processing software. They used Intel microscopes and experienced the advantages of a digital microscope in working with varying levels of visual abilities and motor skills. The microscopes are also compatible with presentation program software, such as *PowerPoint*. In spite of the fact that the class was taught by various instructors, these technological components evolved and remained relatively consistent. Each of these experiences and projects was selected because they represented types of technology that are readily available within local elementary classrooms and because they reflected the state teacher technology competencies.

Action Research

In order to see whether our students were as impressed with the integration of technology as we had become, we gave students in four classes over one academic year (fall 1, fall 2; spring 1, spring 2) a survey at the beginning and end of the course (see Appendix A). We also gave a post-test to a group of VCU students who had previously taken the technology-enriched version of the course, and to a small population of previous students who were now actually in the classroom as teachers (see Appendix B).

Table 1

Question	Groups for Comparison									
	fall1 pre	fall1 post	fall2 pre	fall2 post	former stud.	first yr tchr	spr1 pre	spr1 post	spr2 pre	spr2 post
a- Elem. students should use Excel	2.64	3.30	2.64	3.09	2.83	3.00	2.35	3.06	2.23	2.77
a- Excel can be a valuable tool to teach	2.79	3.30	2.79	3.45	2.78	2.80	2.71	3.06	2.23	2.77
a- I am motivated to use technology to teach	3.14	3.80	3.14	3.82	3.67	3.40	3.59	3.67	3.46	3.69
a- I will/do encourage others to use technology	3.07	3.80	3.07	3.82	3.61	3.00	3.53	3.67	3.38	3.69
a- Inspiration can be a valuable tool	1.79	3.70	1.79	3.36	2.28	1.00	2.00	2.39	1.38	1.69
a- Intel microscope is a valuable tool	1.93	3.80	1.93	3.46	3.44	3.20	2.29	3.44	1.85	3.69
a- Internet is tool to connect with scientists	3.43	3.90	3.43	3.38	3.44	3.00	3.00	3.61	3.23	3.23
a- Internet is valuable tool for students	3.71	3.80	3.71	3.62	3.67	3.40	3.76	3.89	3.54	3.77
a- Internet is valuable tool for teachers	3.86	4.00	3.86	3.69	3.78	4.00	3.71	3.94	3.69	3.92
a- ITV is a valuable tool to teach	2.93	3.30	2.93	3.73	3.17	3.20	3.12	3.56	3.00	3.38
a- PowerPoint is valuable tool for students	3.14	3.30	3.14	3.31	3.33	3.00	2.94	3.33	3.38	3.69
a- PowerPoint is valuable tool for teachers	3.29	3.70	3.29	3.38	3.22	3.20	3.29	3.33	3.31	3.62
a- Software is valuable tool for teaching	3.21	3.80	3.21	3.73	3.28	3.20	3.06	3.56	3.08	3.23
Average	**2.99**	**3.65**	**2.99**	**3.53**	**3.27**	**3.03**	**3.03**	**3.42**	**2.91**	**3.32**
Change		**0.66**		**0.53**				**0.40**		**0.41**
d- Schools have Internet equipment	2.86	3.40	2.86	3.23	3.06	3.20	2.94	3.17	3.00	3.31
p- I am familiar with Inspiration	1.50	3.10	1.50	3.18	2.00	1.40	1.65	2.44	1.46	1.77
p- I am familiar with ITV programs	2.79	3.00	2.79	3.64	2.94	3.00	2.59	3.33	2.46	3.38
p- I am familiar with software	1.79	3.30	1.79	3.31	2.67	2.80	1.88	3.17	2.08	2.85
p- I am proficent at email	3.50	3.50	3.50	3.46	3.33	3.60	3.29	3.67	3.38	3.54
p- I am proficent with the Internet	3.21	3.60	3.21	3.31	3.22	3.40	3.24	3.61	3.15	3.38
p- I am proficient at Excel	3.00	2.70	3.00	3.36	2.50	2.40	2.76	2.78	2.38	2.77
p- I am proficient in PowerPoint	2.79	2.90	2.79	2.85	2.56	2.60	2.65	3.00	2.62	3.15
Average	**2.65**	**3.16**	**2.65**	**3.30**	**2.75**	**2.74**	**2.58**	**3.14**	**2.51**	**2.98**
Change		**0.50**		**0.65**				**0.56**		**0.47**

app- I will use/do use Excel	2.79	3.30	2.79	3.27	2.67	1.80	2.59	3.00	2.15	2.69
app- I will use/do use Inspiration to teach	1.79	3.40	1.79	3.18	2.28	1.00	2.06	2.78	1.54	1.69
app- I will use/do use ITV to teach	3.00	3.30	3.00	3.82	3.17	2.20	2.88	3.50	2.92	3.38
app- I will use/do use PowerPoint to teach	2.93	3.20	2.93	3.08	2.94	1.80	2.53	3.00	2.23	3.00
app- I will use/do use software to teach	3.21	3.70	3.21	3.73	3.22	2.40	3.12	3.61	3.08	3.23
app- I will use/do use the Intel microscope to teach	1.86	3.60	1.86	3.38	3.39	1.40	2.29	3.28	1.62	3.31
app- I will use/do use the Internet to teach	3.14	3.80	3.14	3.23	3.33	2.40	3.35	3.89	2.92	3.38
AVERAGE	**2.66**	**3.13**	**2.66**	**3.17**	**2.86**	**2.33**	**2.63**	**3.05**	**2.43**	**2.81**
Change		**0.47**		**0.51**				**0.42**		**0.38**
u- I have used the Intel microscope	1.71	3.40	1.71	3.23	3.39	2.60	2.06	3.72	1.38	3.54

a= Attitude, p= Proficiency, app= Application

The survey had students rate their attitudes, perceived abilities, and their use of particular types of technology. Results indicated that all three areas showed an increase from pre- to post-course as a result of the VCEPT elementary science methods course (see Table 1). However, the attitude responses showed the greatest positive change and the application responses showed the least amount of positive change.

All groups identified the Internet as a valuable tool for educators. Pre-service teachers' attitudes, perceived abilities, and application of the Internet were consistently high. While 100% of our sample of first-year teachers saw the Internet as a valuable tool, their use of the Internet with students was much lower (only 60%—see Table 1). The value placed on using the Internet with students by all groups was lower than the value they held for their own use of the Internet to teach.

Pre-service teachers were more enthusiastic about the use of the Intel microscope as a result of taking the *TEDU 517* course. While the sample of first-year teachers was small, the data indicated that pre-service students were over twice as likely to use the Intel microscope to teach science than their first-year teacher counterparts.

It is difficult to draw conclusions about the data collected. Consistently throughout all the groups, attitudinal responses showed the most positive change. One might infer that attitudes are the easiest to change and sustain. The application responses showed the least amount of positive change. This may result because application of a particular type of technology could require more long-term and specific professional development. In the authors' views, students' positive attitudes about the use of technology, state requirements for its use, and the potential for other positive effects warrant further study of its implementation.

The authors of this study cannot extend the results further as neither will be working in the School of Education next year. A teacher-in-residence position is temporary and dependent upon budgetary constraints. However, the methods of the elementary science course will continue to be taught the same way, and include much of the technology-related content of the past five years. It is hoped that as the VCEPT project evaluation continues, so too will this study and the tracking of VCU students as they enter the classroom. ■

Bios

Jimmy Johnson was a teacher-in-residence at Virginia Commonwealth University. He has taught fourth and fifth grades in the Hanover County Public Schools for the past twenty years. He holds a Master of Education degree in Curriculum and Instruction from Virginia Commonwealth University and a Bachelor of Arts degree in Elementary Education from Virginia Polytechnic University and State University.

Laura Wilkowski is Assistant Science Instructional Specialist for Richmond Public Schools and a former teacher-in-residence at Virginia Commonwealth University. She has been a member of the VCEPT project for five years and coordinated the Pre-Practicum Apprentice Program and the Clinical Faculty Summer Institute. She holds a post-masters certificate in Administration and Supervision from Virginia Commonwealth University, a Master of Education degree in Science Education from Clarion University of Pennsylvania, and a Bachelor of Arts degree in Elementary Education from Mercyhurst College (Erie, PA).

References

[1] *Technology and Education Reform*, Office of Educational Research and Improvement, U.S. Department of Education, Internet: http://www.ed.gov/pubs/EdReformStudies/EdTech/welcome.shtml

[2] G. Chaika, "Technology in the Schools: It *Does* Make a Difference!" *Education World*, (1999), Internet: http://www.educationworld.com/a_admin/admin122.shtml/

Appendix A

Virginia Collaborative for Excellence in the Preparation of Teachers

Fall 2001 Post-517 Technology Survey

Action Research Project

The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) was a project that began in 1995 and involved collaboration between colleges and universities around the state. One of its goals was to help make teacher preparation classes more constructivist based and to help instructors utilize research to make their classes better in some way. This survey is designed to investigate the use of technology within the classroom. Please help us complete some research as to the Methods of Elementary Science Class (TEDU 517) by answering the questions below.

Semester and Year that you took TEDU 517 ______________________________

TEDU 517 instructor ______________________________

Biographical Information

- Academic classification at the beginning of the fall semester (please circle one)

Freshman Sophomore Junior Senior Graduate Post Graduate

- Grade Level you would like to teach (please circle one)

Kindergarten First Second Third Fourth Fifth Sixth Don't Know

Technology Survey

Please use the following scale to respond to the statements below.

A= Strongly Agree B=Agree C=Disagree D=Strongly Disagree

1. The Internet is a valuable tool for teachers to get new information. A B C D
2. The Internet is a valuable tool for students to get new information. A B C D
3. The Internet is a valuable tool to connect with scientists. A B C D
4. Most schools have equipment to connect to the Internet. A B C D
5. I am proficient at doing research using the Internet. A B C D
6. I am proficient at communicating with others using the Internet. A B C D
7. I will use the Internet to teach elementary science. A B C D
8. I have used the Intel microscope. A B C D
9. Intel microscope is valuable tool for observation. A B C D

10. I will use the Intel microscope to teach elementary science.	A	B	C	D
11. PowerPoint is valuable tool for teachers to use for instruction.	A	B	C	D
12. PowerPoint is valuable tool for students to use in doing presentations.	A	B	C	D
13. I am proficient in using PowerPoint.	A	B	C	D
14. I will use PowerPoint to teach elementary science.	A	B	C	D
15. I am familiar with several examples of elementary science software.	A	B	C	D
16. Science software can be a valuable tool for teaching science.	A	B	C	D
17. I will use software to teach elementary science.	A	B	C	D
18. I am familiar with several instructional television programs.	A	B	C	D
19. Instructional television is a valuable tool to teach elementary science.	A	B	C	D
20. I will use instructional television to teach in teaching elementary science.	A	B	C	D
21. I am proficient at Microsoft Excel.	A	B	C	D
22. Microsoft Excel can be a valuable tool to teach elementary science.	A	B	C	D
23. Elementary students should use Excel (or other spreadsheet software).	A	B	C	D
24. I will use Excel (or other spreadsheet software) to teach elementary science.	A	B	C	D
25. I am familiar with Inspiration software.	A	B	C	D
26. Inspiration can be a valuable tool for teaching science.	A	B	C	D
27. I will use Inspiration to teach elementary science.	A	B	C	D
28. I am motivated to use various technologies to teach within my classroom.	A	B	C	D
29. I will encourage others to use technology in their classrooms.	A	B	C	D

Please describe any especially useful or valuable methods of technology used within the 517 class.

What do you see as your challenges to using these technologies within the classroom?

How do you see yourself using these technologies within your class? Give specific examples. For example, I might use Excel when...

Appendix B
Virginia Collaborative for Excellence in the Preparation of Teachers
Fall 2001 Post-517 Technology Survey for first year teachers
Action Research Project

The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) was a project that began in 1995 and involved collaboration between colleges and universities around the state. One of its goals was to help make teacher preparation classes more constructivist based and to help instructors utilize research to make their classes better in some way. This survey is designed to investigate the use of technology within the classroom. Please help us complete some research as to the Methods of Elementary Science Class (TEDU 517) by answering the questions below.

Semester and Year that you took TEDU 517 ______________________________
TEDU 517 instructor ______________________________

Biographical Information

- Academic classification at the beginning of the fall semester (please circle one)

Freshman Sophomore Junior Senior Graduate Post Graduate

- Grade Level you would like to teach (please circle one)

Kindergarten First Second Third Fourth Fifth Sixth Don't Know

Technology Survey

Please use the following scale to respond to the statements below.

A= Strongly Agree B=Agree C=Disagree D=Strongly Disagree

1. The Internet is a valuable tool for teachers to get new information. A B C D
2. The Internet is a valuable tool for students to get new information. A B C D
3. The Internet is a valuable tool to connect with scientists. A B C D
4. Most schools have equipment to connect to the Internet. A B C D
5. I am proficient at doing research using the Internet. A B C D
6. I am proficient at communicating with others using the Internet. A B C D
7. I use the Internet to teach elementary science. A B C D
8. I have used the Intel microscope. A B C D
9. Intel microscope is valuable tool for observation. A B C D

10. I use the Intel microscope to teach elementary science.	A B C D
11. PowerPoint is a valuable tool for teachers to use for instruction.	A B C D
12. PowerPoint is a valuable tool for students to use in doing presentations.	A B C D
13. I am proficient in using PowerPoint.	A B C D
14. I use PowerPoint to teach elementary science.	A B C D
15. I am familiar with several examples of elementary science software.	A B C D
16. Science software can be a valuable tool for teaching science.	A B C D
17. I use software to teach elementary science.	A B C D
18. I am familiar with several instructional television programs.	A B C D
19. Instructional television is a valuable tool to teach elementary science.	A B C D
20. I use instructional television to teach in teaching elementary science.	A B C D
21. I am proficient at Microsoft Excel.	A B C D
22. Microsoft Excel can be a valuable tool to teach elementary science.	A B C D
23. Elementary students should use Excel (or other spreadsheet software).	A B C D
24. I use Excel (or other spreadsheet software) to teach elementary science.	A B C D
25. I am familiar with Inspiration software.	A B C D
26. Inspiration can be a valuable tool for teaching science.	A B C D
27. I use Inspiration to teach elementary science.	A B C D
28. I use various technologies to teach within my classroom.	A B C D
29. I encourage others to use technology in their classrooms.	A B C D

Please describe any especially useful or valuable methods of technology used within the 517 class.

What are your challenges to using these technologies within the classroom?

Please describe any technologies in which you have been trained since taking the TEDU 517 class.

A COLLABORATIVE PRE-PRACTICUM APPRENTICE PROGRAM GIVES A COMMUNITY COLLEGE A JUMP-START IN TEACHER PREPARATION

G.F. CHILDERS
Div. of Mathematics and Science, J. Sargeant Reynolds Community College
Richmond, VA 23285-5622
gchilders@jsr.vccs.edu

Abstract

The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), funded by a grant from the Division of Undergraduate Education of the National Science Foundation, implemented the VCEPT Pre-Practicum Apprentice Program a couple of years into the grant. Groups of colleges within the Collaborative were to work together to set up an experience for pre-service teachers at their colleges which emphasized mathematics, science, and technology and which gave the pre-service teachers some in-field experience observing instruction in the local schools with lead teachers in these disciplines. Virginia Commonwealth University (VCU), Virginia Union University (VUU), and J. Sargeant Reynolds Community College (JSRCC) formed a collaboration of colleges with the City of Richmond. The carefully planned program of seminars and in-field observations in Richmond Public Schools provided a model program for identifying pre-service teachers and giving them the opportunity to decide if teaching was a career for them. All evaluations of the Program at J. Sargeant Reynolds Community College indicate that it was educational for the pre-service teachers and assisted them in forming their own philosophies of education. Once the VCEPT grant was complete, JSRCC institutionalized the Program by developing a course, *Introduction to Teaching as a Profession*, modeled after the Program, included teacher preparation as part of the Strategic Plan of the College, and created a Center for Teacher Education.

Introduction

The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), funded by a grant from the Division of Undergraduate Education of the National Science Foundation, implemented the VCEPT Pre-Practicum Apprentice Program a couple of years into the grant. Groups of colleges within the Collaborative were to work together to set up an experience for pre-service teachers at their colleges which emphasized mathematics, science, and technology and which gave them some in-field experience observing instruction in the local schools with lead teachers in these disciplines. This article will show how one such group of colleges developed the Program through partnership, and how this effort gave the community

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 145 - 153

college a substantial impetus in teacher preparation. The process used, the seminars developed, the observations experienced, the evaluation of the community college effort, and the impact on the college as the college attempted to address the teacher shortage will be the focus of this article.

Pre-Practicum Apprentice Program

The purpose of the Pre-Practicum Apprentice Program was to give students a chance to view math and science being taught in the public schools and to assist the students in deciding early in their college career whether teaching is the career for them. One goal of the program was that students would begin to form their own philosophy of education. Students received a $6 per hour stipend for up to eight hours of observation in the local schools and for each hour of seminar attendance. The students attended three seminars emphasizing mathematics, science, and technology, and had observation experience appropriate to these disciplines.

Development of the Pre-Practicum Apprentice Program

Virginia Commonwealth University (VCU), Virginia Union University (VUU), and J. Sargeant Reynolds Community College (JSRCC) each appointed a faculty member to develop and coordinate the Program. The three coordinators called a formation meeting and were joined by the JSRCC chair of the Division of Mathematics and Science, the City of Richmond Mathematics and Science supervisors, and the Program coordinator. It was decided that the group of colleges and the City of Richmond would together hold three seminars for the students and would provide observation in local schools. A syllabus was developed describing details of the Program, such as purpose and expectations, guidelines for the observations, and evaluation questions. Ideas on methods of promoting the Program at the colleges were shared. The planning meetings were held on a regular basis the first year to monitor the progress of the Program. As the years of the grant continued, the number of planning meetings decreased, and e-mails and telephone calls were the main source of communication between the coordinators.

Structure of the Seminars

<u>Seminar I</u> — The first seminar essentially remained the same each semester for the full grant period and always lasted one-and-a-half hours. It was always held at VCU approximately one month into the semester to provide sufficient time to recruit the students. Recruitment time was especially important at JSRCC due to the fact that identification of pre-service teachers was

very difficult since there was no education curriculum at the college. The purpose of the first seminar was to help students understand the Program, prepare them for observations in the local schools, explain ways to become certified to teach, and answer their questions.

The topic of the first program was always, "Introduction to the Program, Guidelines for Participation." The seminars began with introductions so students would understand which students were from which college, so everyone would know which level and/or subject each student planned to teach. One of the Program coordinators reviewed the syllabus for the course and emphasized how the students should approach their observations in the public schools. For instance, such topics as dress, proper behavior, ethical concerns, and considerations of class time were discussed. The main speaker, usually from the Department of Human Resources of Richmond Public Schools, explained the different ways that someone can become a teacher in the Commonwealth of Virginia. The pre-service teachers found it very helpful to learn teacher shortage areas. The speaker allowed time for students to ask questions and the students found that this question-and-answer period was one of the greatest benefits of the Program. The students seemed desperate for information!

At the end of the seminar, the students signed up for the schools in which they wished to observe. A social time completing the seminar provided valuable networking opportunities for the students.

Seminar II — The second seminars were the most varied during the four years of the Program. Twice the seminars featured an award-winning math teacher from Mosby Middle School in Richmond discussing his teaching techniques and/or illustrating how to make quick web lessons by inserting photographs and other graphics into the computerized lesson. One of the seminars featured fourth graders who were taken to the James River with graphing calculators, data collectors, and probes and learned to graph the data from real sources, such as water pollution. The pre-service teachers were asked to participate in the program demonstrations. The students also seemed to feel very comfortable in asking questions and in sharing situations which had occurred during their observation experiences.

Two of the most memorable seminars were actually full-day pre-service teacher conferences held on Saturdays and hosted by JSRCC. Other groups of VCEPT pre-service teachers from other colleges in the Collaborative joined with the Richmond group to experience presentations, and mathematics, science, and technology sessions led by faculty from the various colleges. Some of the titles of the sessions were: "Flying through the SOL"; "Teaching the Mathematics SOL with the Newspaper"; "A Teacher Apprentice in Action"; "Learning about the Learning Cycle"; "Fun and Inexpensive Science Activities"; "Finding the Median Fit Line: An Algebra I SOL"; and, "Using Different Learning Styles to Teach Science." The pre-service teachers had time to share their teaching experiences and to demonstrate through exhibits what they had accomplished at their individual colleges.

One spring semester, the pre-service teachers really enjoyed going to Lewis Ginter Botanical Gardens in April for their second seminar. Lewis Ginter has a greenhouse where they meet with City of Richmond school children and provide classes on plants—especially interesting and unusual plants that the children find fascinating. The pre-service teachers experienced some of the same lessons the children had experienced and toured the gardens.

The teaching apprentices met at the Science Museum of Virginia for one second seminar. They were invited to use the resource center whenever they wished. One of the JSRCC students was surprised at this invitation since the student did not really think of herself as a real teacher yet. The student was told, "Just tell whoever is here, 'I am a teacher' because you really are." This conversation marked the importance of teaching apprentices in the community college envisioning themselves as teachers early in their college career. This self-concept is helpful so that the students can develop their philosophies of education, can begin to save materials and collect ideas from workshops that they might incorporate into their lessons in the future, and can develop their self-image and confidence as a teacher. The pre-service teachers were able to use the e-microscopes in the resource center and to browse through the models and materials. Then the students were taken on a very unusual tour of the Science Museum. The tour included offices and the behind-the-scenes efforts necessary to run such a large museum. This seminar not only provided the pre-service teachers a resource for themselves, but also a view of what a field trip for their students could be like.

<u>Seminar III</u> — The third seminars were held at JSRCC. The first year, a professor of mathematics at JSRCC led an interesting program using the graphing calculator, a data collector, and probes. The pre-service teachers were active participants in the program. For instance, a pre-service teacher would walk toward a motion probe, and distance and time were collected at time intervals so close that graphs of the motion of the pre-service teacher were drawn on the

calculator. Students were then shown some graphs and asked what type of motion a person would walk to form the presented graph. This program was very helpful in enabling the students to see how technology can be used in a meaningful manner to convert real life data into abstract algebraic graphs.

During another third seminar, the same mathematics professor conducted a program called "Amazing Animals Using the Casio 9850+." Each student was given a Casio 9850+ graphing calculator and told which buttons to push on the calculator in order to graph drawings of various animals such as rabbits. This program was fun for the pre-service teachers, they had experience with a Casio 9850+ calculator, and the activities could be used later in their teaching. The activities were suited to the upper elementary school or middle school level.

Another seminar program, led by two community college professors, was entitled, "Active Learning Without Technology—Triangles, Patty Paper and Stellation of Tetrahedron (A Hands-On Way to Learn Geometry)." The presenters had the students work with paper in order to learn geometry. The students enjoyed it so much that they did not want to leave the seminar even when the ending time approached. Many of them took paper home and worked on the activities that night. These activities were ones that the teaching apprentices can use in their own teaching of geometry concepts.

The third seminars always included time for paperwork so that the students could turn in their time logs of observations in the public schools. These logs had to be signed by the supervising teacher. The students also turned in their evaluations of the Program. Certificates were presented to those completing the Program, and were encouraged to mention this experience on their future résumés.

In-Field Experiences of the Pre-Service Teachers

The VCEPT Pre-Practicum Apprentice Program provided for ten hours of in-field experience in a local school. The Richmond City Schools was a partner in this collaboration with VCU, JSRCC, and VUU. Letters were sent to the principals explaining the program and asking for their cooperation. For the first year of the program, the pre-service teachers were able to choose any school in Richmond and any grade level. Afterward, however, the coordinators of the Program decided that it would be best to limit the number of schools to approximately three or four near each college and to limit the experiences to the elementary or middle school level. This process was much more successful. The principals expected the students and the students called the principals to arrange their first visit to the schools.

The students had been told during the first seminar that they should get to know the staff in the school's main office, and should sign in and out each day they went to school. The students had been instructed to be prompt so as not to disturb a lesson prepared by the teacher. The pre-service teachers were encouraged to go one hour each week or possibly two hours per week, rather than doing all eight hours immediately. A few students, due to their work schedules and their class schedules, had no choice but to spend an entire day at the school. It was felt that this was better than not having the experience at all. The pre-service teacher's purpose at the school was to observe the components of the classroom environment, the motivation of the students, the discipline issues, the learning style of the students, the technology used in the instruction, the assessment of the students' learning, and the professionalism of the teacher. This purpose had been explained in the first seminar, and the syllabus had a whole page listing techniques to notice in the classroom. Since the pre-service teachers were placed with lead teachers in the schools, it was hoped that they would observe the best practices in these crucial subject areas.

The excitement and dedication observed in most good teachers was also manifested in these pre-service teachers and some observed more than eight hours and/or refused a stipend. Some supervising teachers took special interest in the pre-service teachers and let them be more involved in the classrooms.

Evaluation of the Program at the Community College

Pre-service teacher evaluation of the experience — The first two years of the Program, the students were asked to write a two-page paper about their experience as pre-service teachers. After that, the coordinators designed an evaluation containing four questions for the pre-service teachers to answer. The questions were:

1. What have you learned from your observations about teaching in today's classroom?
2. Have your observations influenced your decision to teach? If so, how? If not, why not?
3. Describe any experiences which moved you.
4. Describe how these observations may or may not have changed your perspectives on the best ways to teach students.

Some of the written responses in the evaluations were:

- " ...it is my firm belief that teaching students is best done through understanding the individual learning styles,..." Michael Moon, Fall 2000

- "There is a lot to teach a child in a day." Paula Katz, Fall 2000

- " I noticed several teachers had the students get up and release some energy—with songs or a reading break so they could concentrate better." Paula Katz, Fall 2000

- "My observations have changed my opinion on how to maintain classroom control. I admired the way the teacher always got the student's attention when they seemed to begin to lose their focus. Instead of yelling or saying 'look up here, please,' she would walk around, ask questions, show cool pictures. This kept excellent order in the classroom and let the children learn while having fun." Sharon Johnson, Fall 2000

- " My goal for attending this program was to see what teaching was like, but in the end I had reached beyond my goal. I had helped students grasp an understanding on a particular problem that gave them confidence in themselves which put a smile on their face as well as mine." Sarah Bertrand, Fall 1999

- "I can now understand more clearly that you definitely have to be more than just book smart. As a teacher you definitely have to care about the students and want them to succeed." Bernice Collins, Fall 1999

- "I've learned you have to be creative and imaginative." Rodira Walker, Spring 2002

<u>Overall evaluation of the program at JSRCC</u> — There have been 105 different students involved in the VCEPT Pre-Practicum Apprentice Program at JSRCC during its four year term. By Summer 2002, there were eighteen graduates from the College who had been involved in the VCEPT Program at some time. Presently, 55 students who have been in the Program are still at the College, so it appears that it might have influenced the retention of these students. Most of the teaching apprentices at JSRCC were in the social science, liberal arts, or science curriculums.

The VCEPT Pre-Practicum Apprentice Program has been considered by some of the mathematics and science faculty (full-time and adjunct) at JSRCC as a valuable part of the VCEPT grant. These faculty assisted the coordinator many times in recruiting participants, in helping with seminars and Saturday conferences, and in helping to arrange special programs for the seminars. The Program also increased the interest of faculty at the College in teacher preparation.

Implications for the Community College

The most direct implication of the VCEPT Teaching Apprentice Practicum at JSRCC is the development of a course, *Introduction to Teaching as a Profession*, that institutionalizes the efforts made with the VCEPT Pre-Practicum Apprentice Program. A committee was formed at JSRCC during Spring 2002—the last semester of the VCEPT grant funds. This committee began by listing the topics that should be included in the course, and finished developing it by Summer 2002. The course has two credits and since there are writing and speaking components in the course, students must place in *ENG 111* at the College in order to be eligible to take it. The course contains an observation component involving ten hours of observation in the local schools. The course topics are: requirements for teacher licensure; school and classroom environments, assessment, and standards; introduction to learning styles; special needs students; curriculum and pedagogy; philosophies of education; technology in education; time management and study skills; transfer opportunities (especially schools of education); and, resources at JSRCC for success in learning. Upon successful completion of the course, the pre-service teacher will:

- report on a direct observation experience in a local school setting;
- design a flowchart of the student's individual path to becoming a teacher;
- explain the multiple roles associated with the teaching profession;
- design a model classroom or school; prepare a bulletin board;
- use the Internet to examine topics in education; use new technologies for teaching and learning;
- prepare a portfolio to demonstrate an understanding of the course content for assessment purposes;
- demonstrate knowledge about teacher entrance exams; and, make presentations on class-related topics.

Realizing the critical teacher shortage in Virginia as well as the United States and the fact that over 40% of the nation's current teachers did course work at a community college [1], JSRCC has added a goal in their new strategic plan: " Increase the number of students in the teacher preparation pipeline to meet the needs of our region." One of the first tasks to meet this goal was to establish a Center for Teacher Education. Having this goal in mind, the development officer of the College proceeded with a proposal to support the new course by finding funds from local businesses and patrons.

Conclusion

The VCEPT Pre-Practicum Apprentice Program will be definitely institutionalized by the offering of *Introduction to Teaching as a Profession*, and by the formation of the Center for Teacher Education. For other colleges desiring the same benefits of such a course, it is recommended that a team-oriented and collaborative approach be used, i.e., enlisting the assistance of college/university coordinators, supervisors, and the principals of the local school system(s). By assigning these participants well defined roles and responsibilities, other pre-practicum apprentice programs are sure to experience the same level of success. ■

References

[1] *Investing in Tomorrow's Teachers: The Integral Role of Two-Year Colleges in the Science and Mathematics Preparation of Prospective Teachers*, National Science Foundation, NSF-9949, 1998, 3.

EVALUATING REFORM TEACHING IN COLLEGE COURSES—ACTION EVALUATION IS ACTION RESEARCH

G. M. BASS, JR.
School of Education, College of William and Mary
Williamsburg, VA 23187
gmbass@wm.edu

Introduction

"Why is the sky on Earth blue?" "What color would the sky be on the moon?" What color would the sky be on Mars?" How can college courses help tomorrow's teachers be more confident in both answering such scientific questions and in helping their own students understand fundamental scientific concepts? The purpose of this paper is to present the results of an ongoing curriculum design and evaluation project to reform college science and math courses and educational methods courses taken by pre-service teachers. Faculty at seven Virginia higher education institutions have collaborated to develop courses that teach a broad-based core of essential knowledge consistent with the national standards reform movement. Elementary and middle school teachers have also been involved in the project on these course development teams and through serving as clinical faculty supervising the pre-service teachers.

After reviewing some historical background on the rationale for curriculum reform in math and science teaching, this paper will present a summary of what professors and their students say about "reformed" college courses in math and science. Interviews were conducted with professors who revised their courses using the fifteen Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) Course Reform Guidelines (listed later in the Procedures and Data Collection section.) Class visits were made to observe these reform courses being piloted during summer school sessions. Course questionnaires were collected from students who took these reformed courses when they were offered during the regular academic year. Since the faculty interviews and class observations were done primarily to provide formative evaluation feedback to project participants, the primary emphasis of this paper will be on the analysis of student surveys from 36 different courses totaling more than 2,000 students. How consistently do students notice different teaching practices in these reform courses? How do these reform teaching practices influence the students' learning? What are the implications of these preliminary findings for future math and science course development and implementation in higher education?

Theoretical Background

During the past five years, the National Science Foundation (NSF) has funded the Collaboratives for Excellence in Teacher Preparation (CETP) program to encourage educational institutions to reform the initial training of K-12 teachers to produce future teachers well prepared in science, mathematics, and technology. Typically each year, three collaboratives have received a three to five year grant to develop innovative ways to prepare future teachers in the areas of science, math, and technology. Consistent with the overall goal of the NSF Division of Undergraduate Education, this program promotes the use of best teaching practices to attract, instruct, and retain the most capable college students for teaching careers. One key aspect of this program is to encourage arts and sciences college faculty to work with education faculty and local school teachers to develop science and math instructional experiences that help students learn in-depth subject matter and essential teaching skills.

The theoretical framework for reform programs such as CETP can clearly be found in the science and math standards-based reform efforts of the past decade. Twelve years ago, the American Association for the Advancement of Science (AAAS) began Project 2061 with the explicit long-term goal to reform K-12 education to produce science literate graduates. Their 1989 report, *Science for All Americans*, identified what all students should know and be able to do in science, mathematics, and technology after thirteen years of schooling [1]. In 1993, Project 2061 published *Benchmarks for Science Literacy* that translates the literacy goals of *Science for All Americans* into explicit learning objectives by the end of grades 2, 5, 8, and 12 [2]. The *National Science Education Standards* [3] released in December 1995 provided a series of standards for: (1) science teaching; (2) professional development of teachers; (3) teachers' development of professional knowledge and skills; (4) science education assessment; (5) content standards organized by K-4, 5-8, and 9-12 grade levels; (6) school district science program standards; and, (7) the science education system beyond the school. Among the six science teaching standards presented in that report, the call for inquiry-based science programs, for the teacher to become a facilitator of student learning, and for ongoing assessment of teaching and student learning are especially important to reforming college science courses.

Other professional organizations have also been actively involved in promoting new ways to reform educational practice. When the National Council of Teachers of Mathematics (NCTM) published its *Curriculum and Evaluation Standards for School Mathematics* in 1989, it began an active discussion of how mathematics should be taught that continues today [4]. The discussion draft of the updated NCTM Standards, entitled *Principles and Standards for School Mathematics* [5], was released in October 1998. The final version of the revised *"Standards"*, released in 2000 is scheduled to be available soon on the newly updated NCTM website [6]. The National Council for Accreditation of Teacher Education (NCATE) has also released its draft elementary standards and assessment guidelines destined to become an integral part of NCATE 2000, NCATE's performance-based accreditation system now under development. These preparation standards identify what new elementary teacher candidates should know and be able to do.

Purpose of Evaluation

How can the impact of educational reform efforts on college courses and student teachers' K-8 classroom performance be evaluated in practical but effective ways? Throughout this project, data have been systematically collected to describe what actually happens in reform classes, how students and instructors respond to these "best teaching practices," and how it affects students as they prepare for their student teaching experiences. Specifically, this evaluation research aimed to answer such questions as: (a) How do faculty and students actually spend their classroom time in a reform designed course? (b) How do students respond to reform-based course features? (c) What do college instructors conclude as they reflect on their reform teaching experience? (d) What influences do such reform college courses have on student teachers' K-8 classroom teaching preparation? (e) What kinds of evaluation strategies and findings best describe and communicate these educational reform efforts to various stakeholders?

Methods

<u>Data Sources</u> — The Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), established in May 1996, consists of four-year institutions (Virginia Commonwealth University, Norfolk State University, Mary Washington College, Longwood University, University of Virginia, Virginia Union University, and the College of William and Mary), two-year institutions (J. Sargent Reynolds Community College, Tidewater Community College, and Germanna Community College), community-based educational institutions (the Science Museum of Virginia and the Virginia Mathematics & Science Center), and local school systems. While

there are five key goals in that project, the focus of this paper is only on one of those goals: large-scale college course development, reform and adoption, and the resulting impact on students.

Course development teams from the various participating institutions spent the first year designing a variety of college math, science, and teaching methods courses. During the summer of 1997, the first group of reform courses was taught at Virginia Commonwealth University (VCU). Teams of two to four professors from the different participating institutions served as the instructors for each course. Students enrolled in the courses were generally non-science majors taking the courses to satisfy general education requirements and included prospective K-8 teachers. During the summers of 1998 and 1999, additional courses were team taught at Norfolk State University (NSU) and Mary Washington College (MWC), respectively. Introduction of these reform courses as part of the required general education coursework was also begun at various participating institutions during the regular 1998-99 academic year and continued into the 1999-2000 school year.

<u>Procedures and Data Collection</u> — The evaluation strategy in this project has focused on assessing the effects of educational reform on several different project efforts. During the first three years, formative evaluation was emphasized to provide ongoing feedback for project planning, monitoring, and administration purposes. Formative evaluation of the VCEPT reform courses was also carried out to provide systematic feedback to both course instructors, course development teams, and the project management team. In the fourth year of the project, evaluation efforts have begun to focus on college course implementation issues. Also, during the fourth year, pilot testing of evaluation procedures and instruments for follow-up impact studies was started.

Selected evaluation data from the first three years will be described to provide some background and context for the project accomplishments. However, this paper will emphasize the conclusions that have resulted from the fourth-year evaluation efforts on course implementation. Specifically, the following questions have guided the Year 4 data collection and analysis. To what degree do these college courses reflect the educational reform standards identified in the course development effort? What actually happens in the college classroom when faculty teach these reform courses? How do college students value the different instructional activities in these reform courses? How do student teachers who have taken these reform courses teach math and science in K-8 classrooms?

Four sources of data have been used to evaluate the impact of the reform-based science and math courses: 1) instructors' description of course, e.g. syllabi, supporting course materials and Self Assessment instrument; 2) classroom observations throughout the summer school courses; 3) end-of-course student evaluation questionnaires; and, 4) individual interviews with course instructors. During Years 1-3, students in the team-taught summer session courses completed an end-of-course evaluation form. After the fall semesters of the third and fourth years, faculty teaching any reform courses in their home institution were also asked to distribute an end-of-course evaluation form.

The classroom observation instrument was designed by the project evaluator to focus on "best teaching practices" incorporated into the course by the individual development teams. It was intended to measure the instructors' whole class instructional behaviors, the students' whole class behaviors, the small group interactions, and individual student presentations and activities using 24 specific classroom behavior categories. College students were recruited to attend the courses as observers. These students were undergraduates with an interest or actual training in becoming certified teachers, but did not necessarily have expertise in the science or math course they were observing. The observers were initially trained by the project evaluator and a weekly meeting to resolve any observation questions was held throughout the summer session. The observers used a five-minute or one-minute time sampling technique to record what was happening in the course.

The primary information sources for the Year 4 evaluation came from two main sources. All VCEPT instructors were asked to complete a Course Quality Assurance Self-Assessment. The purpose of this effort was to use the six VCEPT course development guidelines (identified on the Self-Assessment form included at the end of the paper) as an assessment rubric for judging the VCEPT courses. VCEPT instructors completed this task and shared the results during November on-site visits by the project's external oversight committee, the National Visiting Committee (NVC). Individuals on this committee were mathematics and science content experts selected in consultation with the NSF. In addition to providing the NVC member with helpful information about the course being observed, the completed Self-Assessment forms provided a record of what changes instructors have made in their courses.

Instructors at all the participating institutions teaching VCEPT reform courses were provided with a two-page questionnaire to distribute to their students at the end of the course. Students were given fifteen items reflecting the VCEPT course development guidelines and asked to judge how frequently those characteristics took place in class and to rate the importance of those elements to their own learning (see Appendix A). There were 2,045 student responses representing 36 separate courses from seven higher education institutions. While eight of these courses have multiple sections, all courses were developed to be taught according to the reform practices regardless of instructor.

The course questionnaire asked students to rate fifteen course characteristics representing the essential project guidelines for course reform. These fifteen course development criteria are:

1. active student learning
2. up-to-date teaching technologies
3. connections to other related disciplines
4. connections to the natural world
5. mixture of breadth and depth in coverage
6. interesting and intellectually involving concepts
7. critical thinking about current events
8. practical applications to students' own lives
9. effective interactions among students
10. opportunities to collect pertinent information
11. opportunities to organize information
12. opportunities to analyze information
13. opportunities to communicate conclusions and ideas
14. ethical and social implications in the world
15. assessment of student performance in different ways

Students were asked to indicate the frequency of the VCEPT course characteristics using a five-point scale that included these choices: "Systematic use (100% of classes); Customary use (75%-99% of classes); Frequent use (50%-74% of classes); Moderate use (25-49% of classes); Occasional use (0-24% of classes)." Students also indicated the importance of these VCEPT characteristics in helping them learn in this course by using a five-point scale that included: "Very Important"; "Important"; "Unimportant"; "Detrimental to your learning"; or, "Not Applicable or No Opinion."

Results of Selected Findings from Years 1-3

Summer School Student Questionnaires — The summer school course evaluation data indicated that students were most satisfied with the use of active learning strategies and real life examples of math and science. On the item, "This course increased my ability to relate math/science concepts to 'real world' applications," the range of course means was 2.74 to 3.44 with a median of 3.30. [The end-of-course evaluation form used both four-point "strongly disagree" to "strongly agree" rating scale items and open-ended questions.] The most problematic characteristic of the courses for students was the team teaching. The students' open-ended answers revealed their concern was due to differences in faculty teaching style and how those differences affected course assessment activities. While the course evaluation data showed most students agreed with the in-class participatory activities, between 16% and 23% of the students expressed some dissatisfaction with various aspects of these more active learning approaches. In addition, the course evaluation results clearly showed that a large majority of students planning to teach agreed these courses increased their understanding of both math/science content and math/science teaching strategies.

Summer School Observations — During summer session courses, an attempt was made to assign a student observer to every class. For example, during the 1997 summer session, six of the seven courses had a student observer. Typically, the observers attended a majority, but not all, of the classes. The range was 14 to 21 observation days with a median of 17 and there was no systematic pattern to "missing observation days." Analysis of the data reveals much heterogeneity among the faculty's use of different instructional strategies. For example, the use of classroom lecture varied from 19% to 51% of class time among the six courses. The use of small group student activities varied from 0% to 28% of the observed classes. Student participation during whole class instruction (such as asking and answering questions, providing information or reactions, etc.) varied in the courses from less than 1% to a high of 13% of observed class time. Group or individual problem solving activities varied from 0% to 20% of class time among the six courses. While class size did influence some of these variations, all courses had been developed to stress active learning within an expected class size of ten to fifty students.

Faculty Interviews — Interviews with most faculty were conducted via telephone by the project evaluator. Faculty members were consistently positive about their summer teaching experience with the team teaching element frequently identified as one of the best aspects of the summer course. Since the purpose of the team teaching experience was to encourage professional development among faculty, the reform courses seem to have accomplished that objective. However, some faculty did mention that the unique context, objectives, and class size of the summer school courses were very different from their regular teaching experiences. They acknowledged that the question of how to transfer these "best practices" still requires additional resources or departmental support at their home institutions.

Year 4—Full-scale Course Implementation

The instructors completed the Course Quality Assurance Self-Assessment and submitted it to the project management team for inclusion in the 1999 annual project report. These completed forms were also reviewed by the evaluator and related to the students' course ratings. The student course evaluation results are found in the following four tables:

Table 1 All VCEPT courses - Percentage distribution of student responses
Table 2 Subset of All Mathematics, Science, and Technology courses
Table 3 Subset of All Teaching Methods courses
Table 4 All VCEPT courses — Means & standard deviations

Discussion

Examining the feedback from 2,045 students in 36 courses reveals that the most frequently identified course characteristics were #1 "active student learning" and #2 "up-to-date teaching technologies," with 66% choosing "systematic" or "customary" frequency. The criteria #4 "connections to the natural world" had 64% of students choosing the same two highest categories. Also highly rated by students were #5 "mixture of breadth and depth in coverage" and #6 "interesting and intellectually involving concepts," with 62% of the students indicating these occurred in three-quarters or more of their classes. The two VCEPT course characteristics least often noted by the students were #7 "critical thinking about current events" and #14 "ethical and social implications in the world," with 40% identifying these as occurring with "systematic" or "customary" frequency.

These student ratings do support the conclusion that these course development criteria were evident in most VCEPT courses. Twelve of the fifteen identified course characteristics were rated by 75% or more of the students as occurring in at least half of their classes. The three lowest rated items not meeting this level were #7 "critical thinking about current events," #14 "ethical and social implications in the world," and #8 "practical applications to students' own lives."

These were rated by 65%, 66%, and 72% of the students as occurring in at least half of their courses.

Students also indicated the importance of these VCEPT characteristics in helping them learn in this course by using a five-point scale that included "Very Important," "Important," "Unimportant," "Detrimental to your learning," or "Not Applicable or No Opinion." The three most valuable course characteristics were: #1 "active student learning" (57% chose "Very Important"); #6 "interesting and intellectually involving concepts" (49% chose "Very Important"); and, #15 "assessment of student performance in different ways" (41% chose "Very Important"). The three characteristics reported as least important with only 23%, 25%, and 25% of the students, respectively, choosing "Very Important" were #7 "critical thinking about current events"; #14 "ethical and social implications in the world"; and, #3 "connections to other related disciplines." Since two of these least valuable course characteristics were also the two characteristics least often found in the VCEPT courses, faculty members seem to have matched their reform course changes to reflect student preferences.

The one item which students rated as reasonably helpful to their learning which was not perceived as frequently happening in their courses was #8 "practical applications to students' own lives." Students saw this feature as beneficial (36% rated it "Very Important" and 45% rated it as "Important"). However, it was the third least noted course feature with only 48% of the students acknowledging this happened in at least half of their classes. In fact, 12% of the students selected "Occasional Use" (0-24% of classes) for item #8, the third lowest rating.

Table 4 expresses the students' ratings by weighting their responses on a five-point scale (A = 5, B = 4, C = 3, D = 2, E = 1 for both the Presence items and for the Value items). Again, this way of analyzing the students' ratings reveals the highest rated class frequency was for item numbers 1, 2, 3, 4, 5, and 12. The most valuable for learning were again #1, #6, #2, and #15, as noted above.

Although most of the reform courses were math and science courses, there were seven education courses with a total of 115 students responding to the course questionnaire. *Tables* 2 and 3 show the student ratings separated for arts and science courses and for education courses. While there are individual differences to specific course features, the most dramatic differences can be found in the last three items on the questionnaire. In the math and science courses, 784 of the 1,930 students who responded plan to teach. When asked whether this course experience increased their motivation to try a variety of math and science teaching strategies in their own teaching, 26% "Strongly Agree." Of the 115 students in the teaching methods courses, 83% "Strongly Agree" to that same question. To item 34 asking whether the course increased their understanding of how to use different math/science teaching strategies, 28% of the students in the math and science courses "Strongly Agree" while 76% of the students in the education courses "Strongly Agree." A similar difference was found to the final question about whether the student was likely to share ideas from this course with classmates: 24% of the math and science course students "Strongly Agree" and 68% of the education students "Strongly Agree." While these differences could be due to generally smaller class sizes and a higher percentage of juniors and seniors in the education courses, it could also represent a difference in student purpose for the general education math/science courses and for the education teaching methods courses.

Finally, there was much variation among courses on the four features rated by the students as most important. For example, using the five-point scale presented in Table 4, students' ratings on the frequency of "active student learning," varied from a high course mean of 4.9 to a low of 2.4. To the course feature " interesting and intellectually involving concepts," the perceived frequency rated by students ranged from a course mean of 4.8 to 2.6. On the course characteristic "assessment of student performance in different ways," the course means ranged from 4.5 to 2.6. On the use of "up-to-date teaching technologies" in their classes, the mean student ratings ranged from 4.9 to 2.6. As noted in Table 4, all fifteen course characteristics showed an overall mean of 3.0 or above. However on the four most important course characteristics, there were from three to five courses below the 3.0 level.

These student frequency ratings should provide helpful feedback to course instructors for further development of their courses, especially for the lowest rated courses. Because these instructors have also done a Self-Assessment of their course, it is possible to do a preliminary analysis as to why students reacted so differently. For example, the reform course rated highest on "active student learning" was a "studio physical science" course in which students spent almost all of their class time in small groups working with microcomputer-based and video-based labs. In an education course seen as also encouraging "active student learning," the instructor described her course as involving small group activities (both cooperative learning and group projects) that involved computers, graphic calculators, and student manipulatives. Reform courses that were rated low by students on "active student learning" reported using computer-based homework, Internet assignments, CD-ROM assignments, *PowerPoint* presentations, and some group exercises. Clearly, what is done may not be as important as how it is done and how often it is done. Even within the same course, it was clear that instructor differences made a big difference. For example, among six different sections of the same computer science course, the mean student ratings to "active student learning" were 3.6, 3.4, 3.6, 2.4, 2.7, and 3.6, respectively.

Educational Implications

Although it is important not to overgeneralize from any initial offering of newly developed courses, the results of this evaluation of these reform college science and math courses do allow some tentative conclusions which have important educational implications:

- Designing and delivering a learner-centered reform course are two separate actions— What is listed on the page may not be what is presented in the class.
- Changing experienced professors from their traditional role as "sage on the stage" is a challenge—Skills and preferences developed during more traditional teacher-centered instruction do not always generalize to more reform-oriented, student-centered instruction.
- Changing students' expectations about their math and science instruction is also very important—Not all students respond favorably to traditional lectures, but not all students respond favorably to "active learning" classroom teaching either.
- Students' course assignments and class activities shape their expectations, focus, effort, and ultimately, the kinds of learning that will remain after the course is completed—Students planning to be K-8 teachers can be influenced by their math and science professors' teaching techniques, but these pre-service teachers still tend to focus on content knowledge in these general education courses and focus on pedagogy in their teaching methods courses.
- Connecting student assessment and grading procedures to the reform teaching strategies is critical—Traditional paper and pencil exams testing basic knowledge may undermine a reform instructional approach that stresses student involvement and critical thinking.
- Learning through collaboration and team teaching can be an effective professional development strategy for college professors—Math and science college professors in this project express enthusiasm for observing and discussing course activities, but express less in how to develop the necessary classroom skills and ways to facilitate their students' learning.
- All reform courses do not look the same! The degree of "reform" varies with the course topic, class size, access to technology, and unique instructor qualities—College professors in specific mathematics, science, and education courses will interpret and apply general reform

course development guidelines in ways that reflect their disciplinary background, pedagogic beliefs, and teaching experiences.

- Identifying reliable, valid, and convincing measures of student achievement in reform math and science college courses is difficult—It is easier to get college faculty to discuss learner-centered course characteristics and student activities than to discuss their measures of student learning in their courses.
- Informal conversations with project participants may be more influential than formal evaluation reports—The neutrality you "lose" by being an inside project evaluator can be outweighed by the influence you "gain" through regular participation in project discussions and decisions. ■

References

[1] *Science for All Americans*, American Association for the Advancement of Science, Oxford University Press, New York, 1989.

[2] *Benchmarks for Science Literacy*, American Association for the Advancement of Science: Project 2061, Oxford University Press, NY, 1993.

[3] *National Science Education Standards*, National Academy Press, Washington, DC, 1996.

[4] *Curriculum and Evaluation Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1989.

[5] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1998.

[6] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

Appendix A
VCEPT Course Quality Assurance Self-Assessment

The purpose of this checklist is to assure that the VCEPT criteria for course development are reflected in each VCEPT course. The six guidelines emphasize: (1) active student learning through up-to-date teaching technologies and methods; (2) interconnectedness to other disciplines and to the natural world; (3) practical applications to students' own lives; (4) effective interactions among students and appropriate analysis of information; (5) reflecting standards-based curriculum—both national guidelines and/or Virginia Standards of Learning; and, (6) a variety of student assessment strategies. The full VCEPT course development guidelines are listed below.

General Criteria for Course Development

The Collaborative has adopted the following general criteria for all science, math, interdisciplinary, technology, and methods courses we may develop. These courses should offer a broad-based core of knowledge taught with the goal of producing well-informed citizens. In addition, methods courses should increase knowledge of how to teach math and science to K-8 students.

1. The most up-to-date teaching technologies and methods should be incorporated into these courses as available and appropriate to enhance active student learning.
2. These courses should nurture student awareness and appreciation of the variety and interconnectedness of ways scientists learn about the natural world. Thus, each course should be broad in outlook, encouraging and assisting students to make connections with other related disciplines.
3. These courses should invite, enable, and expect students' active interest and involvement in the subject, beyond the receiving and recounting of information. Students' active involvement in these courses will enable them to hone their abilities to think clearly about current events, to become more deeply involved intellectually, and to relate science and mathematics to situations in their own lives.
4. These courses should create a sense of intellectual community among students and between students and faculty. To foster this, small group collaborations, whenever appropriate, should be built into the course, allowing interactive teams of students to communicate ideas, gather, organize, and analyze information, draw logical conclusions from objective data, and address ethical issues. Internet forums and e-mail could provide additional methods of interaction within the classroom, where appropriate, or outside of class.
5. These courses should provide prospective K-8 teachers with an understanding of the material specified in the Virginia K-8 science, mathematics, and technology Standards of Learning as well as the national standards developed by the National Research Council and the National Council of Teachers of Mathematics.
6. These courses should enable students to demonstrate their mathematics and science understanding in a variety of assessment situations.

Please keep these criteria in mind as you describe your course in the following four sections. Each section asks you to relate the VCEPT criteria to important course development decisions you made about your (1) instructional objectives, (2) course content, (3) teaching activities, and (4) student assessment.

1. Course Objectives

How well do your instructional objectives, identifying what you want students to accomplish by the end of your course, reflect the following VCEPT criteria?

Please circle the appropriate letter on this 3-point rating scale to reflect your self-assessment:

D = Definitely emphasized	[Primary consideration]
S = Sometimes emphasized	[Secondary consideration]
R = Rarely emphasized	[Minor consideration]

The [bracketed number] refers to the specific VCEPT criteria for each phrase.

(1) active student learning [#1]	D	S	R
(2) up-to-date teaching technologies [#1]	D	S	R
(3) connections to other related disciplines [#2]	D	S	R
(4) critical thinking about current events [#3]	D	S	R
(5) practical applications to students' own lives [#3]	D	S	R
(6) effective interactions among students [#4]	D	S	R
(7) ability to collect pertinent information [#4]	D	S	R
(8) ability to organize information [#4]	D	S	R
(9) ability to analyze information [#4]	D	S	R
(10) ability to communicate conclusions and ideas [#4]	D	S	R
(11) ethical and social implications in the world [#4]	D	S	R
(12) standards-based curriculum such as NRC, NCTM, Va. SOL [#5]	D	S	R
(13) assessment of student performance in different ways [#6]	D	S	R

2. Course Content

How well does your course content, including class topics and course readings, reflect the following VCEPT criteria?

Please circle the appropriate letter on this 3-point rating scale to reflect your self-assessment:

D = Definitely emphasized	[Primary consideration]
S = Sometimes emphasized	[Secondary consideration]
R = Rarely emphasized	[Minor consideration]

(1) connections to other related disciplines [#2]	D	S	R
(2) connections to the natural world [#2]	D	S	R
(3) mixture of breadth and depth in coverage [#2]	D	S	R
(4) interesting and intellectually involving concepts [#3]	D	S	R
(5) critical thinking about current events [#3]	D	S	R
(6) practical applications to students' own lives [#3]	D	S	R
(7) information gathering and analysis [#4]	D	S	R
(8) ethical and social implications in the world [#4]	D	S	R
(9) reflects standards-based curriculum - [national professional association guidelines and/or Virginia Standards of Learning] [#5]	D	S	R

3. Class Activities

Among some of the different teaching strategies that can be used to address the VCEPT criteria are the following: Multimedia lecture (with videos, slides, transparencies, CD-ROMs, etc.); Modified lecture -- (includes brief individual or small group activities); "Socratic" dialogue (active teacher questioning & student answering); Small group instruction -- separate discussion/problem solving groups; Small group instruction -- peer teaching (e.g. Jigsaw); Student debates; Simulated role play activities; Technological tools (e.g. Graphing calculators); Computer-based activities or assignments; Team projects using Web-based resources or CD-ROM software; Written assignments -- individual or team; Research-like experiences; Student presentations -- individual or group; Poster sessions -- individual or group; Internet or email discussion forums;

Please list some of the class activities you use in this course that address each of the following VCEPT criteria. (One activity may certainly address more than one VCEPT criteria.)

Guideline (1) Active student learning through up-to-date teaching technologies and methods

Guideline (2) Interconnectedness to other disciplines and to the natural world

Guideline (3) Critical thinking about current events and practical applications to students' own lives

Guideline (4) Effective interactions among students and appropriate analysis of information

Guideline (5) Reflecting standards-based curriculum - national professional association guidelines and/or Virginia Standards of Learning

4. Course Assessment

Among some of the different assessment strategies that can be used to evaluate student knowledge and understanding in a VCEPT course are the following: Quizzes and exams (open or closed book); Presentations/demonstrations (individual or small group); Projects with data collection & analysis (individual or small group); Individual reports/papers (library research; reflection/reaction); Problem sets; Simulations & role-playing; Technological tools (e.g. Graphing calculators); Computer activities or tutorials; Internet-based research tasks; Development of webpages; Required student study groups; and Lesson plans for K-8 students.

Please list some of the course assessments you use in this course to allow students to demonstrate their understanding of course content.

TABLE 1
Virginia Collaborative for Excellence in the Preparation of Teachers
Fall 1999 Evaluation Questionnaire

Feedback on All Courses

Presence: A= Systematic use (100% of classes); B= Customary use (75%-99% of classes); C= Frequent use (50%-74% of classes); D= Moderate use (25-49% of classes); E= Occasional use (0-24% of classes)
Value: A= Very Important; B= Important; C= Unimportant; D= Detrimental to your learning; E= Not Applicable or No Opinion

Number of Respondents = 2045	Presence [%]					Value [%]				
	A	B	C	D	E	A	B	C	D	E
1. active student learning	31.0	35.0	20.3	9.4	4.8	57.1	32.7	7.2	1.2	2.2
2. up-to-date teaching technologies	29.4	36.6	18.0	10.4	5.4	39.0	42.7	14.6	2.4	2.2
3. connections to other related disciplines	16.4	33.0	26.9	15.1	9.1	24.9	51.5	17.4	2.7	3.6
4. connections to the natural world	34.6	29.6	17.9	9.9	8.5	33.0	43.9	15.7	3.0	4.3
5. mixture of breadth and depth in coverage	24.6	37.3	25.1	9.2	4.3	31.3	50.2	12.3	2.1	4.2
6. interesting and intellectually involving concepts	28.9	33.3	23.3	9.6	5.6	49.1	38.7	8.2	2.3	1.9
7. critical thinking about current events	14.3	25.4	25.3	18.1	16.9	23.4	44.3	22.4	3.9	6.3
8. practical applications to students' own lives	19.8	28.4	23.8	16.9	11.7	35.7	44.9	14.2	2.5	2.9
9. effective interactions among students	22.2	31.1	25.3	13.2	8.7	32.0	45.2	17.6	2.6	2.7
10. opportunities to collect pertinent information	20.5	33.4	26.9	12.4	7.0	27.8	47.7	17.9	2.1	4.5
11. opportunities to organize information	23.8	33.3	26.6	11.5	5.2	30.0	49.4	14.7	2.0	4.0
12. opportunities to analyze information	25.0	36.0	25.7	9.2	4.6	34.6	48.8	11.3	2.1	3.3
13. opportunities to communicate conclusions and ideas	21.4	31.3	26.7	13.0	8.2	32.9	48.9	12.3	1.8	3.9
14. ethical and social implications in the world	15.4	24.4	26.5	17.9	16.1	24.9	43.7	20.4	3.0	7.9
15. assessment of student performance in different ways	21.7	30.2	25.4	14.2	8.9	40.5	43.7	10.6	2.2	3.3

Biographical Information

Academic classification at the beginning of the 1999 fall semester

Fresh - 38.3%	Soph - 25.4%	Junior - 17.4%	Senior - 12.6%	Graduate/ Unclassified -4.5%

Do you plan to become (or are currently) certified to teach? [If unsure of grade, mark all those that might apply.]

No = 57.1%	Grades K-5 = 18.4%	Grades 6-8 = 2.7%	Grades 9-12 = 4.7%	Undecided = 9.9%

Students planning to teach used the following four-point scale to respond to these questions:
A = Strongly Agree B = Agree C = Disagree D = Strongly Disagree

Number of Respondents = 897	[%] A	B	C	D
33. This course experience increased my motivation to try a variety of math/science teaching strategies in my own teaching.	33.3	36.3	23.1	8.8
34. This course experience increased my understanding of how to use different math/science teaching strategies.	34.0	41.0	18.1	6.9
35. I will likely share teaching ideas from this course with classmates in 1999-2000.	29.9	36.5	22.3	9.9

TABLE 2
Virginia Collaborative for Excellence in the Preparation of Teachers
Fall 1999 Evaluation Questionnaire

Feedback on Math/Science/Technology Courses

Presence: A= Systematic use (100% of classes); B= Customary use (75%-99% of classes); C= Frequent use (50%-74% of classes); D= Moderate use (25-49% of classes); E= Occasional use (0-24% of classes)
Value: A=Very Important; B= Important; C=Unimportant; D=Detrimental to your learning; E=Not Applicable/No Opinion

Number of Respondents = 1930	Presence [%]					Value [%]				
	A	B	C	D	E	A	B	C	D	E
1. active student learning	28.8	35.4	21.2	9.9	5.1	55.1	34.0	7.6	1.2	2.3
2. up-to-date teaching technologies	27.9	36.5	18.9	10.9	5.7	37.2	43.6	15.3	2.5	2.4
3. connections to other related disciplines	16.1	32.0	27.3	15.6	9.5	23.6	51.6	18.2	2.8	3.8
4. connections to the natural world	33.7	29.6	18.2	10.1	9.0	31.8	44.4	16.2	3.2	4.4
5. mixture of breadth and depth in coverage	23.8	37.2	25.8	9.4	4.5	30.4	50.1	13.0	2.2	4.4
6. interesting and intellectually involving concepts	27.2	33.6	23.9	10.1	5.9	47.7	39.6	8.6	2.4	1.9
7. critical thinking about current events	13.9	25.1	24.9	18.5	17.6	22.8	43.8	23.2	4.1	6.3
8. practical applications to students' own lives	18.1	27.8	24.6	17.7	12.4	33.3	46.4	14.7	2.6	3.1
9. effective interactions among students	19.9	31.3	26.3	13.9	9.2	29.9	46.3	18.3	2.7	2.9
10. opportunities to collect pertinent information	18.9	33.3	27.7	13.1	7.4	26.3	48.0	18.8	2.2	4.8
11. opportunities to organize information	23.2	32.6	27.1	12.1	5.5	28.8	49.5	15.5	2.1	4.2
12. opportunities to analyze information	23.9	35.9	26.2	9.7	4.9	33.3	49.3	11.9	2.2	3.5
13. opportunities to communicate conclusions and ideas	19.5	31.2	27.7	13.7	8.6	30.5	50.4	13.0	1.9	4.1
14. ethical and social implications in the world	15.2	23.4	26.5	18.3	16.8	23.8	43.5	21.2	3.2	8.3
15. assessment of student performance in different ways	20.2	30.1	26.0	14.9	9.3	38.7	44.4	11.0	2.3	3.5

Biographical Information

Academic classification at the beginning of the 1999 fall semester

Fresh - 40.5%	Soph - 26.8%	Junior - 17.5%	Senior - 11.5%	Graduate/ Unclassified - 1.8%

Do you plan to become (or are currently) certified to teach? [If unsure of grade, mark all those that might apply.]

No = 60.4%	Grades K-5 = 15.2%	Grades 6-8 = 2.6%	Grades 9-12 = 4.4%	Undecided = 10.4%

Students planning to teach used the following four-point scale to respond to these questions:
A = Strongly Agree B = Agree C = Disagree D = Strongly Disagree

Number of Respondents = 784	[%] A	B	C	D
33. This course experience increased my motivation to try a variety of math/science teaching strategies in my own teaching.	26.1	39.0	26.4	10.1
34. This course experience increased my understanding of how to use different math/science teaching strategies.	27.8	43.5	20.7	7.9
35. I will likely share teaching ideas from this course with classmates in 1999-2000.	24.4	37.4	25.3	11.4

TABLE 3
Virginia Collaborative for Excellence in the Preparation of Teachers
Fall 1999 Evaluation Questionnaire

Feedback on Education Courses

Presence: A= Systematic use (100% of classes); B= Customary use (75%-99% of classes); C= Frequent use (50%-74% of classes); D= Moderate use (25-49% of classes); E= Occasional use (0-24% of classes)

Value: A= Very Important; B= Important; C= Unimportant; D= Detrimental to your learning; E= Not Applicable or No Opinion

Number of Respondents = 115	Presence [%]					Value [%]				
	A	B	C	D	E	A	B	C	D	E
1. active student learning	67.0	27.8	4.3	0.9	0.0	89.6	10.4	0.0	0.0	0.0
2. up-to-date teaching technologies	55.7	38.3	4.3	1.7	0.0	69.6	28.7	1.7	0.0	0.0
3. connections to other related disciplines	21.7	49.6	21.7	5.2	1.7	46.1	50.4	3.5	0.0	0.0
4. connections to the natural world	49.6	30.4	13.0	7.0	0.0	53.0	35.7	7.8	0.0	3.5
5. mixture of breadth and depth in coverage	39.1	40.0	13.9	6.1	0.0	46.1	51.3	1.7	0.0	0.9
6. interesting and intellectually involving concepts	58.3	27.8	12.2	0.9	0.9	73.0	24.3	1.7	0.0	0.9
7. critical thinking about current events	20.9	29.6	32.2	10.4	5.2	33.0	51.3	9.6	0.0	5.2
8. practical applications to students' own lives	47.0	38.3	10.4	3.5	0.9	75.7	19.1	5.2	0.0	0.0
9. effective interactions among students	61.7	27.8	8.7	1.7	0.0	67.0	27.0	5.2	0.9	0.0
10. opportunities to collect pertinent information	47.8	35.7	13.0	1.7	0.9	53.0	42.6	3.5	0.9	0.0
11. opportunities to organize information	34.8	45.2	17.4	2.6	0.0	50.4	47.8	0.9	0.0	0.9
12. opportunities to analyze information	43.5	37.4	18.3	0.9	0.0	56.5	40.9	2.6	0.0	0.0
13. opportunities to communicate conclusions and ideas	53.0	33.0	11.3	1.7	0.9	73.9	25.2	0.9	0.0	0.0
14. ethical and social implications in the world	18.3	40.0	25.2	10.4	4.3	42.6	47.0	7.8	0.0	1.7
15. assessment of student performance in different ways	47.0	32.2	14.8	3.5	2.6	71.3	32.2	3.5	0.0	0.9

Biographical Information

Academic classification at the beginning of the 1999 fall semester

Fresh - 0.9%	Soph - 1.7%	Junior - 14.8%	Senior - 31.3%	Graduate/Unclassified - 50.4%

Do you plan to become (or are currently) certified to teach? [If unsure of grade, mark all those that might apply.]

No = 0.9%	Grades K-5 = 72.2%	Grades 6-8 = 4.3%	Grades 9-12 = 9.6%	Undecided = 1.7%

Students planning to teach used the following four-point scale to respond to these questions:
A = Strongly Agree B = Agree C = Disagree D = Strongly Disagree

Number of Respondents = 114

	[%]			
	A	B	C	D
33. This course experience increased my motivation to try a variety of math/science teaching strategies in my own teaching.	82.5	17.5	0.0	0.0
34. This course experience increased my understanding of how to use different math/science teaching strategies.	76.3	23.7	0.0	0.0
35. I will likely share teaching ideas from this course with classmates in 1999-2000.	67.5	29.8	1.8	0.0

TABLE 4
Virginia Collaborative for Excellence in the Preparation of Teachers
Fall 1999 Evaluation Questionnaire

Feedback on All Courses - Means and Standard Deviations

Presence: A= Systematic use (100% of classes) = **5**; B= Customary use (75%-99% of classes) = **4**; C= Frequent use (50%-74% of classes) = **3**; D= Moderate use (25-49% of classes) = **2**; E= Occasional use (0-24% of classes)=**1**

Value: A= Very Important=**5**; B= Important=**4**; C= Unimportant=**3**; D= Detrimental to your learning=**2**; E= Not Applicable=**1**

Number of Respondents = 2045	Presence [Mean SD)]	Value [Mean SD)]
1. active student learning	3.8 (0.7)	4.4 (1.2)
2. up-to-date teaching technologies	3.7 (0.7)	4.2 (0.9)
3. connections to other related disciplines	3.3 (0.5)	3.9 (0.9)
4. connections to the natural world	3.7 (0.7)	4.0 (0.8)
5. mixture of breadth and depth in coverage	3.7 (0.6)	4.0 (0.9)
6. interesting and intellectually involving concepts	3.7 (0.6)	4.3 (1.1)
7. critical thinking about current events	3.0 (0.3)	3.8 (0.7)
8. practical applications to students' own lives	3.3 (0.4)	4.1 (0.9)
9. effective interactions among students	3.5 (0.5)	4.0 (0.8)
10. opportunities to collect pertinent information	3.5 (0.5)	3.9 (0.8)
11. opportunities to organize information	3.6 (0.6)	4.0 (0.9)
12. opportunities to analyze information	3.7 (0.6)	4.1 (0.9)
13. opportunities to communicate conclusions and ideas	3.5 (0.5)	4.0 (0.9)
14. ethical and social implications in the world	3.1 (0.3)	3.7 (0.7)
15. assessment of student performance in different ways	3.4 (0.5)	4.2 (1.0)

Biographical Information

Academic classification at the beginning of the 1999 fall semester

[Mean (SD)] 2.1 (0.1)

Do you plan to become (or are currently) certified to teach? [If unsure of grade, mark all those that might apply.]

[Mean (SD)] 1.7 (0.2)

Students planning to teach used the following four-point scale to respond to these questions:

A = Strongly Agree B = Agree C = Disagree D = Strongly Disagree

Number of Respondents = 897

	[Mean (SD)]
33. This course experience increased my motivation to try a variety of math/science teaching strategies in my own teaching.	3.0 (0.6)
34. This course experience increased my understanding of how to use different math/science teaching strategies.	3.0 (0.6)
35. I will likely share teaching ideas from this course with classmates in 1999-2000.	2.8 (0.5)

The Journal of Mathematics and Science:
COLLABORATIVE EXPLORATIONS

Volume 5 Fall 2002

PART II: REGULAR JOURNAL FEATURES

Virginia Mathematics and Science Coalition

A FUTURE TEACHERS CONFERENCE —A VEHICLE TO RETAIN, INFORM, AND INSPIRE NEW AND PROSPECTIVE TEACHERS

J. KASABIAN
Dept. of Mathematics, El Camino College
Torrence, CA 90506
L. FATHE
Center for Teaching Excellence, George Mason University
Fairfax, VA 22312
J.M. DEWAR
Dept. of Mathematics, Loyola Marymount University
Los Angeles, CA 90045

Abstract

The Los Angeles Collaborative for Teacher Excellence (LACTE) Future Teachers Conference is a day-long learning event for beginning and pre-service K-12 math and science teachers. The Conference provides information, resources and connections tailored to the needs of prospective and new teachers. A unique aspect of the conference is that a group of new and future teachers serve as partners with college faculty on the planning committee. Thus the Conference not only serves to educate new and future teachers, but also provides leadership training for the planning team members; and, the presence of prospective and new teachers on the planning team ensures that the conference sessions effectively target the intended audience's interests. This conference is the most popular activity for new and prospective teachers in the Collaborative. Over the five years the conference has been held, its attendance has grown to 120-150 participants annually. A planning handbook is available to assist anyone interested in organizing a similar event.

Background

The Los Angeles Collaborative for Teacher Excellence (LACTE) was one of twenty multi-institutional projects, called Collaboratives for Excellence in Teacher Preparation (CETP), funded by the National Science Foundation to enhance the training of pre-service science and mathematics teachers. During 1995-2001, LACTE brought together ten institutions of higher education in the greater Los Angeles area—community colleges, members of the California State University system, and private colleges and universities—to join the national effort in promoting excellence and innovation in science and mathematics education. The project's goal was to improve K-12 science and mathematics teaching, and to increase the number of students from underrepresented groups who choose a career in teaching.

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 181 - 188

The approach to achieving this goal was four-pronged:

- enhance the teaching skills of college and university faculty, so that they would better educate the prospective teachers, and better model good educational practices;
- provide support for curriculum development and program revision, to allow faculty to develop and revise content and incorporate a variety of effective educational approaches, such as active learning, cooperative learning, inquiry-based teaching, inclusion of formative assessment procedures, and problem-based learning;
- work within the university culture to enhance the status of teaching, both as a career for math and science students, and as a legitimate focus for university faculty; and,
- recruit, retain, and better prepare more students for the K-12 teaching profession through a series of ongoing support structures, including campus-based student groups, teaching internships in schools and informal education settings, and Collaborative-wide events for prospective teachers.

The LACTE Future Teachers Conference was one of the activities the project originated to help recruit, retain, and better prepare its future and new teachers. A pre-service teacher with a high level of academic preparation and a heightened awareness and knowledge about what it means to be a teacher is more likely to do well and stay in the profession. Retention is critical in addressing the current teacher shortage, since fully 11% of the teachers entering the workforce leave the profession after one year. And after five years, the attrition rate reaches 40%, according to *Before It's Too Late: A Report to the Nation* from The National Commission on Mathematics and Science Teaching for the 21st Century [1]. In California, these percentages are even higher. This is partly due to the limited opportunities available for future teachers to learn firsthand about the teaching profession. The document, *Investing in Tomorrow's Teachers: The Integral Role of the Two-Year Colleges in the Science and Mathematics Preparation of Prospective Teachers* makes a strong case that early pre-teaching experiences can provide a student with the support, encouragement, and resources to continue on this career path [2]. The LACTE Future Teachers Conference was designed to do exactly that.

The Conference, offered annually since 1996, developed from a suggestion from the students themselves. In the early years of the project, LACTE sponsored a series of faculty development workshops to assist the college and university faculty in acquiring new teaching tools, and to help them incorporate these into their courses. Faculty returned to their classrooms from these workshops with renewed interest and enthusiasm—an outcome that was not lost on their students, many of whom who were prospective teachers participating in the LACTE project. They approached the project leadership and asked if they could have a similar activity, one that would both inform and motivate. The leaders conferred, and agreed that the students should have their own conference, and that they should play a major role in organizing the event. Thus was born the LACTE Future Teachers Conference.

The Conference

Planning of the day-long Conference begins about three months before the date of the event, and consists of a series of four to six meetings, with additional e-mail and phone communication. Student participation and leadership in the planning process and implementation give this conference a unique perspective. The planning team consists of LACTE students, K-12 faculty and LACTE community college and four-year institution faculty. The faculty members provide advice and support to student planners, an ongoing foundation for the planning process and the historical memory, since the student planners tend to change each year.

Students are active and respected decision makers throughout the process, and deal with virtually every aspect of the Conference except managing the finances. Even there they are kept well informed, so that they understand the various issues involved with securing and budgeting the funding for this type of event. The following lists clarify how the students and faculty work in concert to produce this Conference.

Under the guidance of the faculty, the student planners are responsible for:

- selecting the topics for the sessions;
- identifying and contacting potential speakers for the sessions;
- making arrangements for morning refreshments and lunch;
- preparing the packets for distribution on the day of the conference;
- securing the attendance prizes.

The LACTE faculty planners are responsible for:

- supplying the feedback from the previous year's conference;
- describing desired qualities of speakers;

- supplying contact information for some potential speakers;
- supporting the students as they select and contact speakers;
- preparing and distributing the agendas and minutes for the planning meetings;
- preparing the materials for the packets;
- preparing and distributing correspondence with the speakers;
- handling all financial aspects of the conference.

Student autonomy, in defining the focus and the structure of the Conference, is a hallmark of the event. Although not foreseen at the time the first Conference was being organized, giving students the power to make decisions proved to be very wise because they understood, in way that faculty couldn't, what issues most concerned future teachers. At times, the faculty involved felt that important topics were being left out, or that there might be too great an emphasis on areas that they saw as less critical; but by design, the student planners have the final say as to topics, presenters, and structure. Faculty are there only as advisors and mentors.

At one point in the LACTE project, its National Visiting Committee (an oversight body required by the National Science Foundation on CETP projects) was critical of the absence of Conference sessions devoted to certain issues. However, when they learned that the students, and not the faculty, had made these choices, the National Visiting Committee reconsidered. They agreed that having given the students the mandate to make these choices, the project was obligated to respect them. In the final analysis, the National Visiting Committee applauded the Collaborative for doing so. In addition, the event attendance and the evaluations of the event have shown again and again that the students on the planning team accurately identify the areas of greatest concern to new and prospective teachers.

Early on, the student planners made it clear that they wanted a mix of sessions on "how to teach" math and science topics, and sessions on practical aspects of preparing to become and function as a teacher. Their instincts proved correct; these practical sessions were the popular offerings, and in the later years of the Conference were offered repeatedly throughout the day. They were also the sessions rated most highly by the attendees in their evaluations.

A sense of the types of sessions offered at the Conference can be gleaned from the following list. In the typical conference format, sessions run concurrently throughout the day, with four or five running in parallel.

Classroom Management for the Elementary School Classroom
Classroom Management for the Secondary School Classroom
"Rainbow, Color and Light"—A Science Lesson for the Elementary Classroom
"An Ocean of Air"—An Inquiry Lesson for the Secondary Classroom
"Making Math Meaningful"—A Lesson for the Elementary Classroom
"Math Magic"—A Lesson for Fun for Elementary School Students
"Physics Phun"—A Hands-on Secondary Science Lesson
Using the Graphing Calculator in the High School Math Classroom
A New Teacher Panel for the Elementary Grades (or for Secondary Grades)
The Bilingual and Dual Immersion Classroom
Using Technology in the Elementary School Classroom
Integrated Student-Centered Technology Lessons
"El Niño Impacts"—An Interdisciplinary Lesson for High School Science
Résumé Writing and The Interview Process
The Credential Process in the State of California
A Principal's Advice to New Teachers
How to Evaluate Job Offers: Comparing Salaries and Benefits
How to Become a Substitute Teacher and the Tricks of the Trade

Another unanticipated outcome of the Conference was that it provides new teachers with a venue in which to present their work and view themselves as teachers of teachers, as well as teachers of students. By the third year of the Conference, some of the sessions were being presented by graduates of the LACTE program and by some of the former Conference planners who were by then teaching. It was gratifying to see that these young teachers had carried the lessons of the LACTE project so effectively into their own teaching. It was also exciting to see them sharing these lessons, from their perspective as new teachers, with those following in their footsteps. This "coming full circle," from student to teacher of teachers, is a powerful endorsement for the leadership preparation provided by the LACTE project.

Evaluation

Determining the value of the Conference to the participants has always been important to the LACTE project. All Conference participants are asked to complete an evaluation form at the end of the day. To enhance the return rate on the evaluations, those who complete the evaluation receive a ticket for a drawing for education-related prizes, including books and materials, passes to the local IMAX and museums, and LACTE t-shirts and sweatshirts.

The evaluation instrument was designed to capture student response to the Conference, and how they felt what they've learned would contribute to their teaching, or influence their desire to teach. It was used as a summative evaluation of the current year's effort, and as formative evaluation information for the following year. It also collected demographic data from the participants. This data has shown that the Conference has grown in attendance each year, reached a diverse audience, and expanded to include students from Los Angeles area colleges and universities outside the Collaborative. Over the five years of the Conference, 98% of the participants said that the Conference met or exceeded their expectations. All of the attendees have stated that as a result of attending the Conference, they were either more likely to become a teacher or there was no change in their career goals. Typical comments from evaluations expressing participants' thoughts about their likelihood of becoming teachers were:

- "I made up my mind to teach long ago. This just helped me to see different views and learn many more things that will help me when I teach."
- "My mind did not change. I am more motivated now."
- "I feel even more strongly about teaching and giving students a high quality of education."
- "The information received at the conference gave me a better overview of what lies ahead for me, thus taking away any doubts that I had."

The following comments indicate the value that the attendees found in this event:

- "It is both exciting and beneficial to meet other people with the same goals and ideas, as well as experience professionals sharing their stories and giving concrete help."
- "Before I was afraid of classroom management, but after today's conference, I think I *can handle* it."

- "Thinking about the credential process has been scaring me, but the conference gave me hope."

- "Today's conference really made me feel like a professional. I received a great deal of information and felt that there are supportive people to help me reach my goals."

Summary

The LACTE Future Teachers Conference brings together expert teachers, principals, and teacher educators to address the many questions college students considering a career in teaching have. It provides accurate information, serves as a meeting place for students with similar career interests, and gives participants encouragement to continue on a career path to teaching. The Conference also offers information and encouragement to beginning teachers, helping them address the challenges they face during their induction years.

A significant feature of the Conference is the integral participation of new and future teachers in the planning process, ensuring that the event effectively targets the needs of Conference attendees. Moreover, student planners develop skills and experience required to plan conferences and meetings for their schools, school districts, and professional organizations.

The fact that four other CETP projects funded by the National Science Foundation (located in the States of Washington, Virginia, Pennsylvania, and Maine) have chosen to incorporate a future teachers conference in their projects offers testament to the effectiveness of such a conference in informing, encouraging, and training future/new teachers. Further endorsement was gained when Washington Mutual signed on to support the Conference for the upcoming year.

Although the LACTE Future Teachers Conference focuses on the preparation of K-12 teachers in science and mathematics, this event can serve as a model for future and new teachers of any discipline or grade level. To assist others in replicating this event, a manual that describes how to plan such a conference, *Future Teachers Conference: Planning Handbook*, was produced with support from the Los Angeles Collaborative for Teacher Excellence [3]. The manual explains how to finance, organize, advertise, and evaluate a future teachers conference, including such details as selecting a conference site, choosing a time schedule, finding speakers, organizing registration, documenting the conference with video, and finishing post-conference tasks. A variety of forms, letters, and a sample press release are provided in an appendix of the Handbook.

Conclusion

A conference designed by and for future and new teachers can be a tremendously powerful vehicle for informing and inspiring the next generation of teachers. It gives the planners a chance to build their confidence and leadership skills by working closely with each other, K-12 teachers, and college faculty; and, it helps new teachers build the support community so critical to surviving their first years in the classroom. ■

References

[1] *Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century*, The National Commission on Mathematics and Science Teaching for the 21st Century, Washington, DC, 2000.

[2] *The Integral Role of the Two-Year Colleges in the Science and Mathematics Preparation of Prospective Teachers*, National Science Foundation, Washington, DC, 1998.

[3] J. Kasabian and J. Dewar, *Future Teachers Conference: Planning Handbook*, Los Angeles Collaborative for Teacher Excellence, Los Angeles, CA, 2000, Internet: http://www.lacteonline.org

TRACKING TRANSFER OF REFORM METHODOLOGY FROM SCIENCE AND MATH COLLEGE COURSES TO THE TEACHING STYLE OF BEGINNING TEACHERS OF GRADES 5-12

E. JUDSON
Arizona State University, Tempe, AZ 85287
Eugene.Judson@asu.edu
D. SAWADA
University of Alberta, Edmonton Alberta, Canada
daiyo.sawada@ualberta.ca

Abstract

The purpose of this study was to determine if reformed science and math courses at community colleges and the university were impacting education majors as they began a teaching career. The reformed courses, in contrast to typical lecture classes, implemented inquiry-based methods that emphasized deep understanding of fundamental science and math concepts. Trained evaluators, utilizing the Reformed Teaching Observation Protocol (RTOP) gathered a total of 86 classroom observations to gauge the level of reform that beginning teachers (one to three years' teaching experience) were implementing in grades 5-12. The pre-service experience of the beginning teachers varied from having had zero to four reform courses. Results indicated that teachers who had completed reform college courses instructed in a significantly more reformed manner. Furthermore, analysis of years of teaching experience revealed that, while both control and experimental groups achieved higher RTOP scores as they progressed from year to year, the experimental group significantly outpaced their counterparts.

"At present, both pre-service and in-service teacher education can be characterized as incoherent and fragmented . . . . In neither are the practices organized to carry out the vision of standards-based learning for all." [1]

As highlighted in the quote above, there is a severe lack of continuity and coherence in the pre-service and in-service education of mathematics and science teachers. Attempting to conduct a controlled experiment to conclude whether the graduates of a particular institution teach in a manner more aligned with reformed pedagogy, as compared to graduates of other institutions, would only characterize the incoherence and discontinuity of the domains of pre-service and in-service education. The Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) believes it has made a small step toward bridging this gap. ACEPT has developed an ongoing formative evaluation that facilitates pre-service education, understanding the challenges faced by beginning teachers while making known to school districts the reforms being instituted at local colleges. In some cases, the two establishments have even partnered to

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 189 - 207

form new pre-service/in-service institutions specifically aimed toward aiding the development of pre-service and induction teachers.

The guiding objective of ACEPT's proposal to the National Science Foundation (NSF) was "to better prepare K-12 teachers in science and mathematics." Entering the fifth and final year of funding, the Evaluation Facilitation Group (EFG) began focusing on the evaluation of beginning teachers. Gathering quantitative data regarding teacher performance, as it relates to reformed teaching, became a priority. An end product of the ACEPT project is the classroom teacher who has enrolled in reformed science and math pre-service courses. In order to evaluate the effectiveness of ACEPT, these ACEPT teachers and a control group of non-ACEPT teachers were identified and assessed. There was a need to test an assumption that is well expressed by the adage, "teachers teach the way they were taught." ACEPT hypothesized that if inquiry learning and improved classroom culture are incorporated into science and math college courses, then pre-service education students will be able to transfer this reformed pedagogic style to the K-12 setting. ACEPT tested this hypothesis.

Review of Literature

Current support for reform of science and mathematics curriculum and classroom practice has been advocated for several years [2-5]. Studies have examined how these reforms, endorsed by teacher colleges, manifest in practices and beliefs of beginning teachers. Such research provides insight into the epistemological and contextual barriers encountered in actual classrooms. The National Center for Research on Teacher Learning (NCRTL) queried more than 700 teachers and teacher candidates before, during, and after their participation in formal teacher education programs [6]. Known as the Teacher Education and Learning to Teach (TELT) study, the NCRTL researchers were primarily concerned with investigating what teachers learned about teaching and learning while participating in different educational programs. The findings of the TELT study discredited several common myths about teacher education. Among the TELT findings was the understanding that majoring in an academic subject does not provide the knowledge needed to teach the subject. Teachers who majored in the particular subject they were teaching were often no more able than non-majors to explain concepts effectively to students. Interestingly, the TELT researchers did find one university-based series of courses that seemed to make a difference: in this series, students were required to reason about the subject, to argue about alternative explanations for what they encountered, and to test their ideas and those of others. Another myth debunked was the notion that short-term in-service workshops are an effective device to improve teaching practice. It was suggested that teaching practices are only likely to undergo substantial changes "when teachers have extended, ongoing assistance that is grounded in classroom practice." This is supported by Robinson's assertion that beginning science teachers should be encouraged to reflect on and make explicit the concepts that are connected to the teaching and learning of science [7].

There is also a general indication from the literature that actual teacher practices may not be akin to teacher beliefs about instruction. As stated by Boethel and Dimock, "there is a real danger that teachers are making only superficial changes while believing that they are implementing constructivist teaching approaches." [8] According to survey data, less than one-fourth of first-year math teachers reported having students use manipulative materials at least several times a week despite their belief that using manipulatives helps students learn and understand mathematics [9]. Marlow and Stevens noticed that actual classroom observations of science teachers in elementary and high school classrooms did not reflect the reform assertions of the teachers [10]. Marlow and Stevens point out that a focus on student-directed and open-ended inquiry was not as evident in the classrooms as teacher statements would have one believe. Costenson and Lawson outlined likely reasons as to why practice does not support reported beliefs; they reported such reasons as a lack of time, an innate belief that inquiry teaching is too slow a method, and personal discomfort [11].

An examination of current literature related to the practices of beginning science and math teachers reveals great reliance on two data sources. While some studies depend upon self-reporting (interviews, questionnaires) for insight into teacher practice [9,12,13], other studies incorporate field notes obtained from classroom observations [7,10,14,15,16]. In either case, pedagogical style is not quantified, but rather characterized.

Method of Evaluation

Beginning teachers were evaluated using a three-step method: (1) beginning teachers were identified; (2) evaluators observed the teachers and quantified the level of reformed practices; and, (3) data collected from classrooms were analyzed using statistical methods.

Identifying Teachers — Although ACEPT has impacted college courses of future K–12 teachers, limited resources demanded a focused effort during the first year of evaluation. The decision was made to concentrate effort on middle school and high school teachers (i.e., grades 5-12). Several techniques were utilized to locate beginning teachers and gain access to their classrooms. In some cases, first-year teachers were approached directly at orientation meetings that were part of the district's regimen. In one local district, ACEPT presented a proposal of evaluation to department heads who then relayed the information to beginning teachers. In another local district, a strong partnership was created with the district's resource staff. This collaboration allowed the appeal for consent of teachers to be filtered through official district channels, thus leading to a high level of participation. The uniqueness of a post-baccalaureate program, designed specifically to prepare science and math teachers, resulted in a direct approach. These post-baccalaureate students were phoned individually and informed of ACEPT's intentions.

Because of the voluntary nature of the process, there was a factor of self-selection on the part of the teachers. Teachers would elect to be observed by an ACEPT evaluator. As part of the Summer 1999 plan of evaluation, those teachers choosing to be part of the research would be provided a generalized assessment of their lesson along with appropriate commentary by the ACEPT evaluator.

<u>Formalizing the Observation</u> — The Reformed Teaching Observation Protocol (RTOP) had been used by ACEPT in the evaluation of university and community college faculty. However, this would be the inaugural use of the RTOP in actual K-12 classrooms. Evaluators were people identified as understanding reformed instruction, had a background in science and/or math education, and partook in approximately eight hours of RTOP training. By the end of Fall 1999, seven evaluators had contributed observational data.

During the evaluation period, many classroom teachers were visited more than once. In some cases, two evaluators would visit a teacher to observe and rate the same lesson. In such instances, although the two evaluators might afterward discuss thoughts on the lesson, actual RTOP scores were not shared until officially entered into the database. In all but one district, the teacher was aware of the exact observation time. Later analysis would reveal no significant difference between announced and unannounced observations. Evaluators were blind as to what pre-service institution the teacher had received credentials from, with the exception of the post-baccalaureate program.

<u>Dealing with Data</u> — As observations were completed, RTOP data were submitted to a central location and entered into a database. Before data entry was complete, waiver forms were checked to identify the teacher's pre-service institution. If the teacher was a graduate of Arizona State University, then registrar records were cross referenced to determine how many ACEPT courses had been completed. The number of courses completed was dubbed "level of ACEPT." In the

case of the post-baccalaureate program, the program of study was scrutinized to ascertain how many of these courses could be considered reformed and differed markedly from the typical education track. A conservative judgment of three courses was made.

In the statistical analysis, RTOP scores were the dependent variable. These were analyzed in terms of several independent variables including content, grade level, and level of ACEPT. A strategy used in conducting these analyses was to stratify teachers based on years of experience. For example, when comparing ACEPT prepared teachers with non-ACEPT prepared teachers, the sample was stratified into first-year, second-year and third-year teachers. It should be noted that since few observations were conducted of third-year teachers, these data were aggregated with second-year teacher data. Further sampling during the three-year evaluation extension will overcome these sampling limitations. Comparison of means was utilized to compose visual representations of data (box plots, bar graphs) and *t*-tests were employed to determine significance. In anticipation of more complete, and perhaps more sophisticated, analyses in the future, all beginning teacher data were entered into an SPSS computer file.

Evaluation Findings

During the first four months of evaluation (Fall 1999 semester), 86 observations were completed. Of these 86 observations, 53 were of teachers who had taken at least one ACEPT course, and 33 observations occurred in classrooms of non-ACEPT teachers. Comparison of the ACEPT and non-ACEPT teachers revealed a significant difference in the level of reformed instruction as based on average RTOP scores for the groups (Table 1).

Table 1

Comparison of ACEPT and Non-ACEPT Teachers

	ACEPT	Non-ACEPT
n	53	33
RTOP Mean	51.1	42.6
Std. Dev.	18.4	12.4
t	2.584	
p	<.05	

In close analysis, and partly because of small sample sizes, significant differences between ACEPT and non-ACEPT teachers did not consistently hold true when examining subgroups (e.g., first-year science teachers, second- and third-year middle school teachers). Factors such as district environment and teacher's gender were weighed in the study to determine their effect within the subgroups. Only "years of teaching experience" was determined to be a key factor. To distill variations occurring when first- through third-year teachers are compared within subgroups, teachers were to be compared only with those of equivalent experience. As noted previously, due to small sample size, data of second- and third-year teachers were aggregated.

Level of ACEPT — To examine the hypothesis that more exposure to ACEPT courses leads to more reformed teaching, the data were divided into three levels of ACEPT exposure (no ACEPT, one ACEPT course, two or more ACEPT courses).

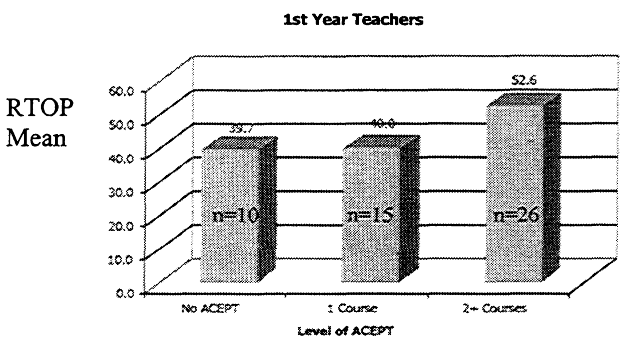


Figure 1

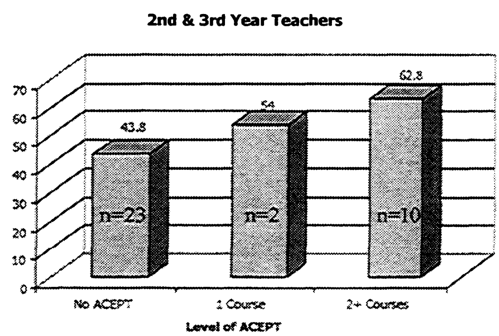


Figure 2

Figure 1 suggests that having one ACEPT course is no better than having none. There is no discernible difference of instruction between first-year teachers who have not taken ACEPT courses and those with only one ACEPT course. Together, Figures 1 and 2 indicate that having two or more ACEPT courses makes a considerable difference. Although Figure 2 depicts a positive relationship between RTOP score and the level of ACEPT, the smallness (n=2) of the one-course group is a definite limitation.

Content and Grade Level — For the analyses to follow, "ACEPT teachers" shall be defined as those who have taken one or more ACEPT courses. With this convention in place, whether examining first-year teachers or the more experienced second- and third-year teachers, a significant difference in the level of reformed instruction was discovered when comparing the

ACEPT experimental group to the control group. A close analysis of subgroups based on content and grade level revealed interesting findings. Among first-year teachers, RTOP scores varied significantly, except for science teachers and teachers of grades 9-12. Among second- and third-year teachers, a statistically significant difference endured when examining subgroups of science and math (Tables 2 and 3).

Table 2

First-Year Teachers - Comparison of ACEPT and Non-ACEPT Teachers

	Overall	Science	Math	Grades 5-8	Grades 9-12
ACEPT RTOP Mean	48.1 (n=41)	41.9 (n=23)	56.1 (n=18)	58.1 (n=16)	41.8 (n=25)
Non-ACEPT RTOP Mean	39.7 (n=10)	43.2 (n=6)	34.5 (n=4)	38.0 (n=5)	41.4 (n=5)
t	2.04	-0.213	5.462	3.235	0.072
p (2-tail)	=.05	.834	<.05	<.05	.943

Table 3

Second- and Third- Year Teachers — Comparison of ACEPT and Non-ACEPT Teachers

	Overall	Science	Math	Grades 5-8	Grades 9-12
ACEPT RTOP Mean	61.3 (n=12)	56.1 (n=7)	68.6 (n=5)	60.8 (n=5)	61.7 (n=7)
Non-ACEPT RTOP Mean	43.8 (n=23)	33.6 (n=5)	46.6 (n=18)	41.1 (n=14)	48.0 (n=9)
t	3.408	3.222	5.107	2.294	1.952
p (2-tail)	<.05	<.05	<.05	.063	.073

Figure 3 graphically demonstrates that years of experience and ACEPT strongly effect RTOP scores.

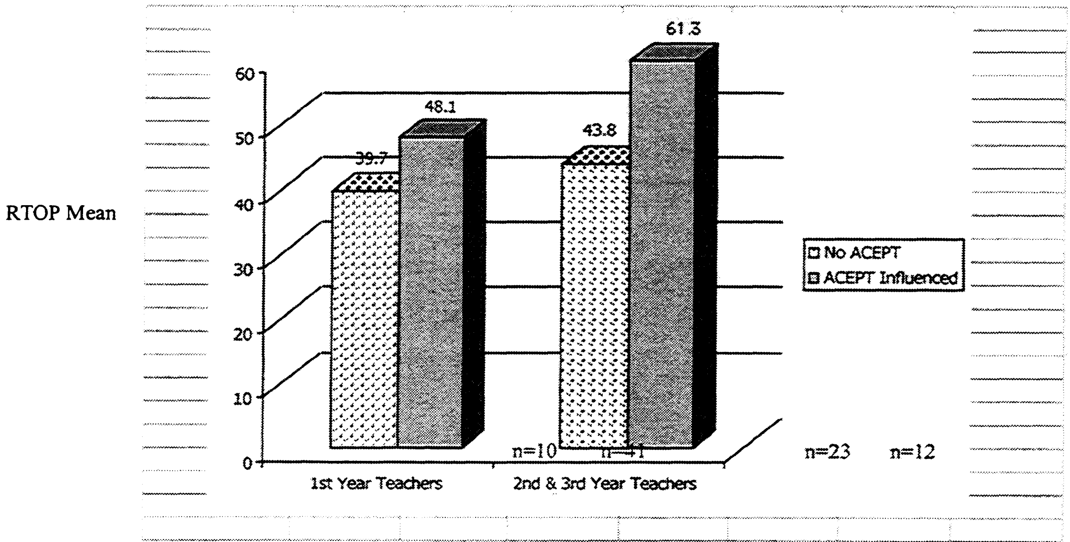


Figure 3

<u>TEAMS</u> — The post-baccalaureate program described previously is formerly known as Teacher Education for Arizona Mathematics and Science (TEAMS). The TEAMS program has graduated four cohorts of students, the first in 1997. Graduates of the first three cohorts were observed and their instruction gauged with the RTOP instrument, as were other teachers. The selection of the control group for comparison to TEAMS warrants a brief discussion. To compare TEAMS teachers to all teachers who had not graduated from this post-baccalaureate program would propose that the control group include teachers who had taken other ACEPT courses. Prudence and judgement dictated that TEAMS be compared to a combination of teachers who had never taken ACEPT courses and teachers who had taken only one ACEPT course.

Although the sample of first-year TEAMS teachers outperformed the control group, a statistical difference between the two groups was not discovered. Second- and third-year TEAMS teachers are considered to be teaching in a significantly more reformed manner (Table 4).

Table 4

Comparison of TEAMS and Non-TEAMS Teachers

	1st year teachers		2nd & 3rd year teachers
TEAMS RTOP Mean	47.0 (n=17)		60.2 (n=6)
Non-TEAMS RTOP Mean	39.9 (n=25)		44.6 (n=25)
t	1.496		2.314
p (2-tail)	.143		< .05

Discussion

Broadly, ACEPT is seen to be accomplishing the goals laid out in its initial proposal. Viewed collectively, RTOP observations demonstrate that ACEPT teachers teach in a more reformed manner than the control group teachers. ACEPT has been able to essentially pop their heads into the classrooms of beginning teachers and check up on teaching practices. Gauging the practices of graduates provides insightful information and leads to stirring questions. Such a follow-up is a rare connection between pre-service and in-service institutions. Stratifying the data in an alternate form or focusing on subsets did not put ACEPT-prepared teachers in a poor light; rather, such sifting led to a number of interesting patterns suggestive of further hypotheses.

In order to sharpen the analysis of the data, ACEPT teachers were compared to control group teachers with the same level of experience. From this emerges the question, "what is the relationship between years of experience and reformed instruction?" When comparing years of experience, both ACEPT and non-ACEPT teachers post striking RTOP gains. A review of field notes and informal conversations with ACEPT evaluators indicate that first-year teachers struggle far more with classroom management. Common sense also leads one to conjecture that a completely novice teacher will grapple to institute any cohesive pedagogy. This is consistent with the findings of Chang who indicated that beginning science teachers tend to transmit content knowledge to students and seldom are observed using the most appropriate instructional practices [14]. It is posited that learning to teach is itself a constructivist activity. As teachers gain comfort with factors, such as classroom management and content, they begin to construct practical alignment between the theory of university experience and the learning environment of the classroom.

Indeed, the RTOP instrument addresses elements typically associated with both inexperienced and experienced teachers, such as lesson design and effective communication. Close scrutiny of RTOP scores reveals that in all but one subsection (Propositional Knowledge) ACEPT and non-ACEPT teachers post gains as teaching experience increases. Moving from the first year of teaching to the second year, gains are "statistically significant" for ACEPT teachers in all subsections of the RTOP except Propositional Knowledge. A similar examination of non-ACEPT teachers reveals no significant gains occurring within any subsection (Table 5).

Table 5

Comparison of RTOP Subsection Mean Scores

RTOP Subsection	**ACEPT Teachers**				**Non-ACEPT Teachers**		
	1st Year (n=41)	2nd & 3rd Year (n=12)	*p* (2-tail)		1st Year (n=10)	2nd & 3rd Year (n=23)	*p* (2-tail)
Lesson Design & Implementation	8.56	11.25	.025		6.10	7.35	.199
Propositional Knowledge	11.85	13.58	.137		11.40	10.78	.643
Procedural Knowledge	7.98	10.50	.042		5.30	6.52	.231
Communicative Interactions	9.32	12.08	.022		7.20	9.13	.052
Student/Teacher Relationships	10.44	13.92	.005		9.70	10.00	. 786

That teachers acquire skills allowing for more effective instruction as they gain experience comes as no surprise. However, what does emerge as a trend is that ACEPT teachers are outpacing the control group in every subsection.

The general hypothesis that enrolling in ACEPT courses leads to greater reformed instruction may be overly simplistic. In addition to showing that one ACEPT course has little or no impact (Figures 1 and 2), the data also imply the possible existence of a critical threshold point. At the threshold, it can be hypothesized that the teacher is likely to adopt a more innovative teaching style; below the threshold, the ACEPT teacher is not dissimilar to the more traditional non-ACEPT teacher. This more refined "threshold hypothesis" is consistent with data collected in other ACEPT settings and supported by the NCRTL survey of over 700 teachers [6]. For example, in the setting of summer workshops, the notion "one course is not enough" becomes "one workshop is not enough." A question related to this idea of exposure is one of self-selection: after encountering their first ACEPT course, might students who relish the inquiry method seek out further ACEPT courses? At Arizona State University, students are notified of the courses endorsed by ACEPT. An attentive student could consciously choose to avoid or to select further ACEPT courses.

Supporting the concept that ACEPT teachers outpace the control group are data related to the specific disciplines of science and math (Tables 2 and 3). For science, no statistical difference exists between the ACEPT and non-ACEPT teachers during the first year of teaching. However, a significant ACEPT effect emerges during the second year of teaching for both math and science teachers. Considering the composite data previously discussed, this is not an unanticipated finding. What is an unexpected observation is that math teachers often achieve considerably higher RTOP scores than science teachers (the exception being first-year non-ACEPT). Collectively, beginning math teachers have an average RTOP score of 51.77, while science teachers only average 43.50. This is nearly a 20% difference. If an observer were able to view a typical science classroom through a window, there is a good chance it would superficially appear more reformed than an archetypal math classroom. One might observe science students working as groups and handling equipment as the teacher walked from one group to another. However, the RTOP instrument allows for the fine-tuning that detects actual dynamics and critical thinking occurring during a lesson. What ACEPT evaluators surmise is that science classes have remained more prescriptive than their math counterparts. Although science students are often assigned to work as groups in class, they are not necessarily pressed toward true inquiry. Such classroom activity may be denoted by what Moscovici termed "activity*mania*," *wherein* there exists a series of disconnected hands-on experiences [12]. The metaphor of "cookbook science" still applies in classrooms, even where the teacher may sense he or she has adopted reforms. Meanwhile, math teachers are adopting several techniques to make their classes more engaging. No longer the exclusive property of science classes, math students are often found working collaboratively, discussing and critiquing problem-solving techniques. Beginning math teachers also seem to be more productive at asking higher-order questions and putting the onus upon students to discover patterns and explain their thinking. Perhaps because the subject of math is inherently not as interesting for most students, math teachers have embraced reform methods with greater fervor.

Table 6

Comparison of Math and Science Teachers

RTOP Subsection	Math (n = 45)	Science (n = 41)	*p*
Lesson Design & Implementation	9.09	7.49	.068
Propositional Knowledge	12.38	11.07	.067
Procedural Knowledge	8.38	6.80	.063
Communicative Interactions	10.40	8.32	.009
Student/Teacher Relationships	11.53	9.83	.035
Total RTOP score	51.78	43.51	.022

Table 6 indicates that math teachers are achieving greater reform gains in a well-rounded manner. That is to say, for two of five subsections of the RTOP, math teachers score significantly higher than science teachers; for the remaining three subsections, the difference of scores remains impressive. Yet, the researchers are open to the criticism that the many math teachers chosen for this study may not be representative of the general population. More than half of the math teachers observed in this study were in a district that has a well developed, reformed math curriculum and provides ongoing support in the way of targeted professional development and mentoring to support the reform math curriculum. This consideration is aligned with the findings of LaBerge and Sons who discovered that, in terms of the factors felt to contribute to successful implementation of the NCTM standards, more than 75% of the teachers in grades 5-12 cited their principals' support and support of other faculty [9].

ACEPT evaluators have collected RTOP data in a variety of settings. These environments have included large college lectures, small recitation classes, and laboratories. Early evidence indicates that there may be inherent factors associated with these different environments that can be both conducive and obstructive to reform methods. Among the beginning teachers, second- and third-year ACEPT teachers are the highest performing with an approximate sixty-point RTOP score. Yet ACEPT has not yet positioned itself to state at what RTOP level instruction may be defined as reformed. Indeed, the unique settings of middle school and high school present challenges for the reform-minded teacher. College instructors who have embraced reformed pedagogy have received RTOP ratings consistently over eighty points; such scores have yet to be observed in the K-12 classroom. It is possible to predict that the upward trend observed from the first to the third year of experience will continue and ACEPT evaluators need merely visit more experienced classroom teachers if they wish to observe highly reformed classrooms. However, such an extrapolation may be overly simplistic; "years of experience" is an omnibus variable harboring many complexities. Other factors such as beliefs, available resources, school expectations, and reasoning skills should be considered in further investigations. Offered as modest insight into the particular challenges faced by beginning classroom teachers, vignettes are included in this paper (see Appendix A). These vignettes may help the reader better understand how obstacles to student-centered teaching may at times become boundaries.

Conclusion

Scrutiny of the beginning teacher data generates discussion that poses further questions for investigation. Yet while examining subsets of data leads to contemplation and even controversy, one strong conclusion may be drawn from the statistics. ACEPT courses do meaningfully affect students who later become classroom teachers. Noteworthy in this effect is the finding that students who have taken two or more ACEPT courses go on to teach in a significantly more reformed manner than people who have had either one ACEPT course or no ACEPT experience. In this sense, completing two ACEPT courses may be taken as a threshold criterion for being "ACEPT-prepared." In turn, students reaching this criterion may be said to have taken an ACEPT "program" (especially true in the case of TEAMS). Teachers who have graduated from an ACEPT program are able to transfer reformed methodology to K-12 classrooms. The adage that was mentioned at the beginning of this report holds true: teachers do indeed teach as they were taught. ACEPT teachers are delivering a much higher level of inquiry-based instruction. ■

References

[1] S. Mundry, B. Spector, K. Stiles, and S. Loucks-Horsley, *Working Towards a Continuum of Professional Learning Experiences for Teachers of Science and Mathematics*, National Institute for Science Education, Madison, WI, 1999.

[2] *Benchmarks for Science Literacy*, American Association for the Advancement of Science: Project 2061, Oxford University Press, New York, 1993.

[3] *Curriculum and Evaluation Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 1989.

[4] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.

[5] *National Science Education Standards*, National Research Council, Washington, DC, 1996.

[6] *Findings from the Teacher Education and Learning to Teach Study*, National Center for Research on Teacher Learning (NCRTL), 1992, Internet: http://ncrtl.msu.edu/full.htm.

[7] S. Robinson, *A Narrative of a First-Year Science Teacher*, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA, 1995, (ERIC ED417947).

[8] M. Boethel and K.V. Dimock, *Constructing Knowledge with Technology: A Review of Literature*, Southwest Educational Development Laboratory, 1999, Internet: http://www.sedl.org/pubs.

[9] V.B. LaBerge and L.R. Sons, "First-Year Teachers' Implementation of the NCTM Standards," *PRIMUS*, **9** (1999) 139-156.

[10] M.P. Marlow and E. Stevens, *Science Teachers' Attitudes about Inquiry-Based Science*, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA, 1999.

[11] K. Costenson, and A.E. Lawson, "Why Isn't Inquiry Used in More Classrooms?" *The American Biology Teacher,* **48**(3) (1986) 150-158.

[12] H. Moscovici, *Activitymania and Inquiry Science Teaching – How do Power Relationships in Classrooms Affect these Different Approaches?* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA, 1998.

[13] K. Nagy, A. Collins, R. Duschl, and S. Erduran, *Changes in Science Teachers' Practice & Beliefs: Progress Toward Implementing Standards-Based Reforms*, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Boston, MA, 1999.

[14] H. Chang, *The Nature and Assessment of Teaching Competency in Apprentice Science Teachers*, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA, 1998, (Eric ED418871).

[15] N.H. Klepper and J.P. Barufaldi, *The Induction Years: Pathways and Barriers to Effective Practice for the Middle School Science Teacher*, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA, 1998, (ERIC ED418867).

[16] C. Yei, K. Wang, and S. Huang, *A Comparative Study on the Use of Questioning Strategies between Beginning Teacher and Experienced Teacher*, Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA, 1998, (ERIC ED418861).

Appendix A

(Points of Interest on the Graph)

While aggregated data can provide understanding of trends, statistical significance, and even predictive ability, close examination of particular cases can yield greater insight into challenges faced by beginning teachers. Of course, how each beginning teacher confronts their particular challenges will be influenced by factors that include beliefs about instruction, self-efficacy, school support, and pre-service preparation. Following a tenet of inquiry, the following vignettes are not presented as conclusive evidence to wholly explain the experiences of beginning teachers. Rather, these sketches represent different settings and mindsets that were not singularly influenced by any one variable. It is for the reader to construct his or her own significance from these situations.

JD: Searching for support — JD is a graduate of the third cohort of ACEPT's TEAMS program, a fast paced, post-baccalaureate program aimed at preparing individuals to become technology-based science and mathematics teachers for grades 5-12 with secondary certification and middle school endorsement. During his pre-service preparation, JD was enthralled with the program. In fact, following his graduation date, JD continued that summer with the TEAMS program as a graduate student to assist with the orientation of the incoming TEAMS cohort. JD was considered by his professors to be a bright, intelligent young man who would be well liked by his students. JD chose a teaching position that outwardly seemed challenging but rewarding. JD soon learned that the position he selected had several hidden demands.

Excited to teach an integrated science and math curriculum and wanting to make a difference in the lives of economically deprived children, JD took a position in an inner city school that had recently instituted a new science and math integrated curriculum. JD taught a combined eighth grade science and math course that was blocked into 100-minute periods. At the same time, Paul (pseudonym), another graduate from the same TEAMS cohort took a similar position at this school. What JD and Paul soon discovered was that though their school had instituted a new concept of integrating science and math curricula with an earnest vision of student benefits, the school had not adopted any particular program for implementation. It was up to the individual teachers to form their own agenda, create lesson plans, and develop hands-on materials. All of this was in addition to managing a student body that did not largely share JD and Paul's beliefs of how education was the key to success, nor did the students share the experience of their teachers' middle-class backgrounds. Yet, JD was determined to make his class a successful learning environment. JD turned to the experienced math and science teachers at his school for assistance. However, while the reformed curriculum was supposedly required of all teachers, most of these teachers still taught the two disciplines as separate entities. Largely, the veteran teachers continued to provide the same science and math lessons from years prior, emphasizing their area of expertise. Regarding day-to-day activities, JD would have to develop or find his own materials if he wished to truly implement the new curriculum. However, JD's attention was soon diverted from the dilemma of content to the problem of classroom management. JD found several of his students to be disrespectful and even unruly. Considering the often uncooperative student attitudes, attempting to organize hands-on materials soon seemed daunting to JD.

When JD was visited late in the fall semester of his first year of teaching by ACEPT, he was clearly able to articulate his challenges, but did express that he was still enjoying teaching. The experienced teachers had provided JD with helpful suggestions on how best to maintain order and JD had gained, if not respect, at least quiet cooperation from his students. JD said that he and Paul had jointly decided to put aside the integrated curriculum and concentrate on classroom management. They were teaching science this first semester and would teach math during the spring semester. When JD instructed his class, he did indeed implement many of the elements of inquiry learning. Yet, there was a very stilted feeling to his classroom. Though students were performing an experiment and were to determine the effects of altering variables, JD had set up the experiment in a very structured manner. Students did not develop any of their own hypotheses and their discussion was perfunctory, related only to completing the task at hand. JD was aware of the tight control, but this lesson was a type of compromise between the sort of open-ended inquiry he wished to implement and the type of discipline he felt his students required.

During that first school year, JD and Paul often carpooled, sharing classroom stories, talking about lesson plans, and commiserating. Compared to JD, Paul was handling his situation less well. Paul had frequent student disciplinary problems that were not abating. Additionally, Paul was internalizing the problems and continued to feel aggravated even when he was away from school. Before the school year ended, Paul had resigned his position, leaving JD to make the drive alone.

JD remarked that he and Paul, along with two other beginning teachers (all from the TEAMS program), often socialized that first year of teaching. The four friends had all taken challenging middle school positions. The other two teachers, like Paul, both quit their positions before the school year ended. While both of these teachers took new positions the following year in conditions perceived to be better suited to their content expertise and teaching style, Paul never returned to teaching. It might be said that JD survived the peculiar challenge of not falling victim to his own support group. Apparently, the other three teachers were comforted in their decisions by knowing that they were not the only ones reneging on their obligations.

Yet, JD knew that he would not be happy if he continued to teach in this school. He felt unsupported in his aspirations to build a reform classroom. The emphasis of the school's personnel seemed to be on heavy-handed discipline and the students seemed more comfortable with a traditional style of teaching. With the onset of JD's second year of teaching, he found himself taking a new position in a suburban district. He teaches eighth grade science in a middle school where he indicates he feels far better supported.

<u>Laura: Nurtured toward reform</u> — In JD's case, it is simplistic to place blame on the nature of an inner city school. Parents may seem less supportive, even wary of teachers. Students might appear more accustomed to a traditional classroom. Administrative emphasis on "basics" possibly accents a lack of confidence in students to benefit from higher order, thinking instruction. In fact, research has shown students of lower socioeconomic status receive less instruction rooted in higher order thinking skills. Laura, a graduate of TEAMS' first cohort of students is a math teacher who has met the challenges of implementing reforms in an inner city school. Interestingly, Laura's school is no more than two miles from the school where JD taught during his first year of teaching. The schools are in the same district with similar ethnic and economic

status of student populations. Also similar to JD's experience was that Laura took a position at her school at the same time, as did a peer from TEAMS, Gwen. Laura was to teach eighth grade math and Gwen was assigned to fifth and sixth grade science. A striking contrast to JD's first school is the organization of Laura's school. While JD taught at seventh and eighth grades at a junior high school, Laura teaches in a K-8 school. For grades K-4, Laura's school draws only students from the immediate neighborhood. For grades 5-8, the school is a magnet school for science and math; thus, it attempts to attract enthusiastic middle school students from within the district who have demonstrated an interest in science and/or math.

Laura reflects that her first year of teaching was particularly arduous. Long hours, developing lesson plans, and dealing with discipline were among her challenges. It can be said that these challenges are not distinct from those faced by most beginning teachers, and even most veteran teachers. Like many beginning teachers, Laura too confronted the task of aligning the type of instruction she valued and had envisioned in her classroom with what seemed to work for her students. But Laura's school staff proved to be extremely supportive and reassuring. Her school had developed a tradition of student participation and was persistent in its efforts to involve parents. Fellow teachers provided Laura with lesson suggestions and earnestly valued her ideas. Laura discovered that, although she would have to instill structured discipline in her classroom, the most reliable source of a well managed class stemmed from engaging lessons. Her peer, Gwen, also proved a valuable source of solace. Although she and Gwen taught different grade levels and content, Laura found it beneficial to discuss with Gwen the theoretical basis and the underpinnings of reform learned during their pre-service experience. Through these discussions, Laura was able to place in perspective how the sometimes seemingly abstract concepts of reform education could effectively be put into place in her classroom. Laura has also maintained communication with the TEAMS program during the past few years through occasional use of the TEAMS listserve, telling her peers about her experiences and directing her former classmates to interesting education websites. Additionally, Laura was selected by TEAMS, during her first year of teaching, to visit with the National Science Foundation in Washington, DC. By her fourth year of teaching, Laura agreed to mentor a TEAMS student teacher.

When Laura's classroom was last observed by ACEPT, she and her students represented a wonderful *supportive* community. Despite that much of the lesson time was devoted to reviewing math homework, a typically mundane chore, Laura's class demonstrated remarkable collaborative efforts. Students took it upon themselves to explain to other students their solutions and were accepting of varying methods. Laura asked questions that were rarely directed toward a single student presenting a problem; rather, she impelled pupils to consider the merits of another's work —to articulate appreciation and provide suggestions when needed. In a sense, Laura was promoting a fellowship of support mirrored in her own professional experiences.

PROGRAMS THAT WORK

L.D. PITT — Section Editor
Depts. of Mathematics and Statistics, University of Virginia
Charlottesville, VA 22904

Each year the Virginia Mathematics and Science Coalition recognizes programs that have been particularly effective in enabling more people to be successful in mathematics and science. The Coalition is particularly interested in recognizing programs that are effective working with individuals from groups that have not traditionally been fully represented in these areas, including minorities, women, and individuals from rural and inner city areas. In the year 2000, eleven programs were recognized and reports of their work were included in a special issue of this journal, Volume 3 No 2.

In 2001 the following programs were recognized:

- Project MATRIX: *Mathematics and Talent Recognition: Instructing for Excellence*; Charlottesville City Public Schools,
  M. K. Murray, Project Director
- *Saturday Morning PACE* (Parent and Child Education) of Richmond City Public Schools and the Mathematics & Science Center,
  D. J. Bagby and *P. A. Priestas*, Project Directors
- *Bridges to the Baccalaureate* Program at J. Sargent Reynolds Community College and Virginia Commonwealth University,
  D. Neely-Fisher, Project Director
- CHROME: *A Pre-College Program in Science, Mathematics, Engineering and Technology*,
  E. G. Wilson, Director
- *Math Made Easy* mathematics program at Tidewater Park Elementary School of Norfolk,
  M. Artis, Mathematics Specialist

The Journal of Mathematics and Science: Collaborative Explorations Volume 5 (2002) 209 - 219

- Project STEP: *Student and Teacher Excellence Program* of Newport News Public Schools,
  W. D. Lett, Superintendent, and *T. Woods,* Director

Articles reporting on the first three of these programs appeared in Volume 4 No 2. This issue a new regular "Programs That Work" section is initiated, and a report on CHROME appears here. The remainder of the 2001 programs and the programs recognized in 2002 will be reported on in this section in future issues.

CHROME: A PRE-COLLEGE PROGRAM FOR SCIENCE, MATHEMATICS, ENGINEERING, AND TECHNOLOGY

E. G. WILSON
Cooperating Hampton Roads Organizations for Minorities in Engineering
Norfolk, Virginia 23501

Program Description

The Cooperating Hampton Roads Organizations for Minorities in Engineering (CHROME) is a pre-college outreach program for science, mathematics, engineering, and technology that serves Hampton Roads, Virginia. With the goal of promoting minorities' preparation for careers in engineering and other high-technology fields, representatives from business, industry, government, institutions of secondary and higher education, and other community organizations created CHROME. Today, our eighteen-year effort represents a highly effective partnership of over seventy organizations.

Concerns regarding the trend of students' declining interest and preparedness in science-related careers and, in particular, the lack of participation in these fields on the part of minorities and females dating to the early 1980s, have been validated by the present shortage of a technical work force in America. While the rapidly expanding job market demands many more workers with these skills, the number of undergraduates earning computer science, engineering, and other technical degrees has diminished despite a national concern for our future work force. Moreover, demographic trends indicate that women and minorities will continue to comprise an increasing proportion of new workers. Increased participation in the fields of science, engineering, and mathematics is necessary, therefore, not only for economic equity, but also for the economic survival of our nation.

CHROME's ultimate goal is to increase the number of minorities and females who continue their education after high school and who major in scientific or other related disciplines. We serve thirteen school districts in Hampton Roads through a range of proven and effective pre-collegiate programs that include: CHROME clubs, regional programs, Saturday and summer academies, leadership workshops for students, teacher-training institutes, internships, scholarships, and family programs.

The CHROME model centers on school clubs that have mathematics, science, and engineering as their focus and on the teachers who serve as club sponsors. One of the major advantages of the club structure is that it provides a continuous nurturing process for students from elementary school through high school. At the elementary school level, the emphasis is on identifying and nurturing students who have an interest in mathematics and science. Students participate in age-appropriate activities designed to encourage interest, as well as lessen fear, of those subjects. At the middle school level, students are provided with enriching experiences in math and science, and are encouraged to begin course selection in these subjects so they will be prepared for more advanced classes in high school. By high school, students have had sufficient positive, meaningful experiences in math and science to help them narrow their career choices. Adrienne Godette, of Crestwood Middle School/Chesapeake, Virginia, wrote, "The reason why I joined the CHROME club at my school was because I have always been interested in the way math and science interact with each other. The CHROME club is an excellent place to learn about science and math and I have learned a lot from the program. I feel that everything we see and use today involves math and science."

Crucial to the success of the CHROME model are the teachers who sponsor school clubs. Ideally, each club has a team of sponsors: a mathematics teacher, a science teacher, and a guidance counselor. As official advisors for the CHROME club, these educators act as liaisons between school administration officials and the CHROME organization, as well as plan activities for club meetings. Some member school systems provide stipends for their club sponsors, while other teachers work on a voluntary basis. We do encourage school administrators to grant release time for training activities and to provide funds for substitute teachers.

Sponsors enjoy outside academic opportunities as a result of their participation in CHROME: many teachers have served as summer program coordinators, have worked on various committees for the CHROME Board of Directors, and have participated in research projects. For example, teacher-sponsors serve as mentors to pre-service teachers at Norfolk State University as part of a grant project funded by NASA. We also honor a "Sponsor of the Year," an award that carries with it $1,000 from the Engineers Club of Hampton Roads.

Meetings with school administrators and teachers are held throughout the year in order to recruit new school clubs and teacher-sponsors. Once a school signs on, CHROME staff members make follow-up visits to coordinate training in club procedures, as well as in programs for the classroom and for club meetings. After that, teachers join in yearly training events, including Sponsor Launch and Sponsor Appreciation Day. Also, each school is provided with a *CHROME Procedures Manual* and a *CHROME Resource Directory*. The *Directory* helps guide participants to resources within the organization. Teacher-sponsors, school clubs, and CHROME member organizations are all linked through our newsletter, *Bits and Pieces*, and via the website at www.chrome.org.

As a component of the model, CHROME collaborates with academic institutions, businesses, technical associations, museums, and community organizations to offer regional programs that complement club activities. Each member organization designates an official representative who serves as the primary liaison between their office and CHROME. These liaisons reflect the diversity of CHROME's partners, who range from CEOs to practicing engineers and from public school administrators to university faculty.

Representatives often have been the prime movers for new program ideas and new collaborations. For instance, Sandy Bottom Nature Park implemented a new summer program in 1998 for elementary CHROME students called the Junior Rangers Program. This study of environmental science has now become an annual program that attracts 75-100 children. In another partnership activity, three clubs are involved in a NASA research project in collaboration with an Old Dominion University Department of Engineering faculty member.

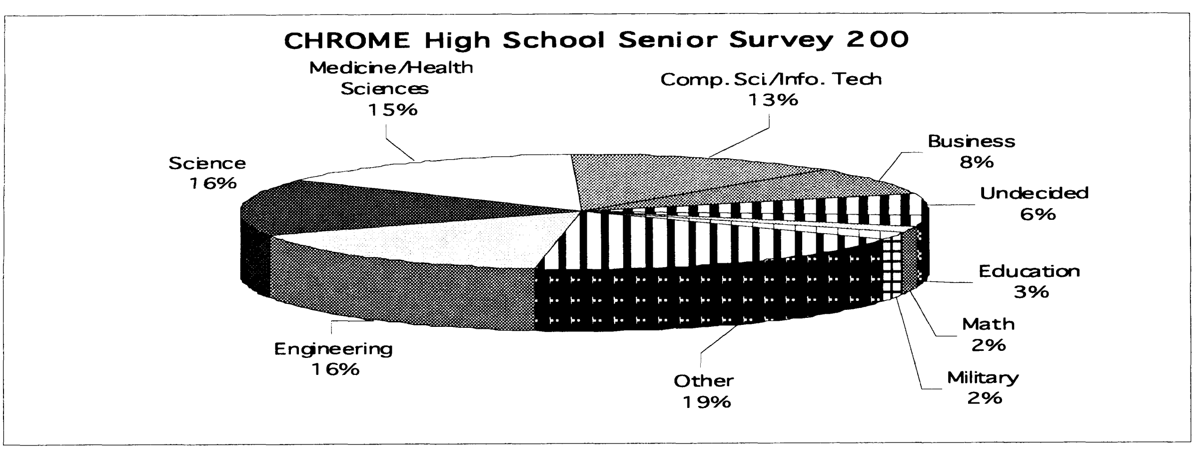
CHROME Staffing Structure

The Board of Directors is elected by the membership and is responsible for developing policies, as well as governing the organization. Overall responsibility for the day-to-day operation of CHROME is handled by the executive director, currently Eleanor Wilson. She keeps the Board apprised of programming activities, acts as principal fundraiser and public relations person, and serves as the point person for establishing relationships with officials from businesses, colleges, universities, and community organizations.

A resource manager assists Ms. Wilson with recruiting teacher-sponsors, counselors, and students for participation in programs and events; with training for teachers; and, with coordinating all area-wide student programs, which are run in concert with our affiliated organizations. Within each member school system, an administrator serves as the CHROME representative. Three systems also have created the position of CHROME Club Coordinator to facilitate and oversee club development and activity.

Our Success Story

CHROME currently has over 130 clubs in elementary, middle, and high schools in the Hampton Roads area. More than 3,000 students and 300 teachers participate annually. Since the program's inception, an estimated 17,000 students have participated in the clubs and we have followed over 4,000 of our alumni into college. Typically, 90% of CHROME seniors go on to college, with more than 60% majoring in science, mathematics, engineering, or related fields.



An Adaptable Model

The CHROME model has proven to be adaptable to a wide variety of scholastic settings: it works for small and large school systems, in rural and urban settings, and for community clubs.

For example, the Newport News School System, a large, urban district of 42 schools, received funding from the National Science Foundation to establish a CHROME club in every school. The Rural Outreach Project, a collaborative initiative of CHROME, Norfolk State University, and NASA, piloted the club model in the rural communities of western Tidewater in 1997. Within three years, the project boasted success with more than 400 students participating from middle and high schools in the City of Franklin and Southampton County.

The first community club was formed in 1989 by Susie Keele, a retired teacher interested in promoting CHROME at the elementary level in the city of Portsmouth. This club provided the impetus for expanding the elementary model to Hampton. And, CHROME became an international model in 1996 when we hosted a visit from representatives of the University of Stellenbosch, in Capetown, South Africa, who saw our program as a potential prototype for their country's educational reform effort.

A long-term commitment to CHROME's mission is evidenced by the fact that many of the organizations currently represented in the CHROME consortium are charter members. Our organization is governed by a board of directors that includes: leaders from Hampton Roads businesses, such as Ford Motor Company, Newport News Shipbuilding, Dominion Virginia Power, and Verizon; representatives from governmental agencies, such as NASA Langley Research Center; and, educators from local school systems, as well as area colleges. This consortium offers a tapestry of resources that may be drawn on for CHROME club meetings, and for summer and regional programs.

CHROME has received statewide, as well as national, recognition for innovative and effective programs. These awards include: 1) *Programs That Work* (2001), Virginia Mathematics and Science Coalition; 2) *Exemplary Partnership in Math, Science, Engineering, and Technology* (2001), Quality Education for Minorities in Engineering (QEM); 3) *Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring* (1997), National Science Foundation; 4) *Best Grassroots Effort in Support of Education* (1994, 1995, 1996), USA Today; 5) *Best Community-Wide Educational Partnership in Virginia* (1994), Virginia Governor's Community Award; and, 6) *A Model Program for Increasing the Academic Pool of Minority Students for Higher Education* (1992), Commonwealth of Virginia.

Budget and Funding

CHROME was created in 1983 under the auspices of the Planning Council of Norfolk, Virginia. Incorporation occurred in 1985, and CHROME was made independent of the Planning Council in 1987; we now operate as a non-profit organization. In 1993, the CHROME Board of Directors invited proposals from member institutions of higher education in the Hampton Roads area to support the expanded growth of the program. Old Dominion University offered the most comprehensive package, which provides office space, personnel, and operating expenses. As a result, CHROME is housed in the College of Engineering and Technology at the University. We also maintain an affiliation agreement with Norfolk State University, the former home of CHROME.

In general, our program is supported by contributions and grants from private corporations, academic institutions, and annual membership fees. CHROME also receives a substantial amount of services and materials donated by member organizations. Since our founding, NASA has provided our primary financial support, with grant awards totaling more than one million dollars. These grants, sponsored in collaboration with Norfolk State University, have underwritten the development and expansion of the CHROME club model and regional activities. Additional funding has been received from the National Science Foundation and the State Council of Higher Education in Virginia. Recently, the Development Committee was established by the Board of Directors to support expanded grant activity and to increase membership contributions.

Over the years, we have found that extensive effort is needed each year to maintain existing club programs. Year to year, many teachers and counselors transfer to different schools, have additional responsibilities added to already full plates, or leave the school system entirely. Administrators, too, frequently change job positions; with such changes, we can never be sure of consistent support. As we embark on new efforts to expand CHROME programs, as well as respond to requests for the creation of new clubs, additional funding and administrative support are needed to keep pace with the growth. It is often impossible to predict new levels of funding, let alone maintain current support, due to the economic dynamics of government and business.

Even with the difficulties of keeping up with staffing changes and raising funds, CHROME programs have a proven record. Our success is documented by an extensive, tested tracking mechanism and database of students who participate in CHROME activities. The database is updated continually and used to assess program effectiveness, track student progression through the academic pipeline, and maintain regular communication with students, parents, and teachers. The basis for all CHROME programs involves the use of data collected throughout our participants' pre-college years. Upon graduation, students are entered into the alumni database, by which their progression through college and graduate school may be monitored. An alumni survey of those now in the work force is currently underway to provide additional information on participants' careers.

The ongoing assessment of programs has been crucial in identifying effective educational techniques: building upon these successful approaches has enabled CHROME to become a powerful, as well as an efficient, program that has had a positive effect on increasing the number of underrepresented minorities and females studying mathematics, science, engineering, and/or technology.

New Opportunities for CHROME

Although significant progress has been made by CHROME in Hampton Roads, much remains to be done. While well on our way to achieving the goal of serving each middle and high school in the region, adding over 170 elementary schools will be a considerable challenge: currently, we serve 45 elementary clubs. Major efforts on behalf of the CHROME central office, in cooperation with area school systems, will be needed to support new growth, as well as extend existing programs. The Board has been engaged in a strategic planning process to address the expansion of CHROME. We recognize that growth requires a new infrastructure and are currently evaluating the financial and programmatic ramifications of any increased activity.

One of our goals is to support educational policies consistent with the CHROME mission in the areas of science, mathematics, engineering, and technology. With the adoption of the Standards of Learning in 1995 by the Commonwealth of Virginia, we seek to align our programs with both state and national guidelines [1].

In recent years, our program has become a statewide, as well as national, leader in the conception and implementation of pre-college programs for minorities and females in math, science, engineering, and technology. CHROME is an outstanding example of what oan be done to help pre-college students envision and realize their career aspirations.

Candy Johnson, a parent, believes that, "Every child, every parent, every teacher, every benefactor—everyone involved with CHROME taps into an almost limitless network of ideas, resources, and people working together to create bigger and brighter tomorrows (and todays) for us all." Our success story is one of ambition, collaboration, and achievement, and speaks to the excellent, resolute work of many individuals and groups: *having a dream* for our students, *supporting the dream* for our associates, and *living the dream* for our young professionals. ■

References

[1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

INTERVIEW WITH ELEANOR WILSON

Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?

A: If you were to trace my career, one might think that I had the perfect plan in place to reach my current position of Executive Director of CHROME. In fact, I began my college career as a Communication Arts/Journalism major with the hopes of landing a writing position with a nationally recognized magazine. Although I never pursued a communications career, my degree positioned me for diverse positions that required good communications skills. I later returned for a master's degree in education with a human resource development focus.

From my first job in an education center, to a career in human resources in private industry, to a ten-year university tenure in cooperative education, and now to director of a non-profit pre-collegiate program—all of these jobs centered on academic and career management programs. Moreover, they all involve linkages between the academic and business communities.

Q: Have you been involved in similar programs? Was there a particular moment or stimulus that caused you to begin this project?

A: Yes, as Assistant Director of Cooperative Education at Virginia Commonwealth University, I coordinated two pre-collegiate programs, namely the Adopt-A-School Program and the Going for the Goal Project. Both programs targeted minority students and assisted them with academic and career preparation. In the previous ten years of my employment, I was working with newly funded programs in which I helped design the programs.

Now, as Executive Director of CHROME, I have primary responsibility for sustaining an organization that has been in existence since 1983. I must give credit to the founders of CHROME. Since I began my tenure in 1997, I have been impressed with the ingenuity, creative energy and continuous support for a "program that works!"

Q: Have there been any unique or unexpected consequences for you resulting from your project?

A: CHROME is now entering a new life cycle in its history. In the past seven years, participation in CHROME doubled. The challenge has been to keep funding at the same pace as the growth of the organization.

Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on CHROME? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?

A: Each day in CHROME is rewarding. CHROME has created new possibilities and opportunities for the many students, teachers, and parents we serve. The youth inspire you with their excitement for learning and our community partners motivate you with their continuous support. In my career, I have the opportunity to work with aspiring professionals of all ages. The greatest reward is in helping youth to bring their dreams to fruition and working with the many volunteers who are committed to this program.

AIMS & SCOPE

Articles are solicited that address aspects of the preparation of prospective teachers of mathematics and science in grades K-8. The Journal is a forum which focuses on the exchange of ideas, primarily among college and university faculty from mathematics, science, and education, while incorporating perspectives of elementary and secondary school teachers. The Journal is anonymously refereed, and appears twice a year.

The Journal is published by the Virginia Mathematics and Science Coalition.

Articles are solicited in the following areas:

- all aspects of undergraduate material development and approaches that will provide new insights in mathematics and science education
- reports on new curricular development and adaptations of 'best practices' in new situations; of particular interest are those with interdisciplinary approaches
- explorations of innovative and effective student teaching/practicum approaches
- reviews of newly developed curricular material
- research on student learning
- reports on projects that include evaluation
- reports on systemic curricular development activities

The Journal of Mathematics and Science: Collaborative Explorations is published in Spring and Fall of each year. Annual subscription rates are $20.00 US per year for US subscribers and $22.00 US per year for non-US subscribers.

All correspondence, including article submission, should be sent to:

Karen A. Murphy, Editorial Manager
The Journal of Mathematics and Science: Collaborative Explorations
Virginia Mathematics and Science Coalition
Richmond, VA 23284-2014
FAX 804/828-7797
e-mail VMSC@vcu.edu

- For article submission, send three copies of the manuscript.
- The body of the paper should be preceded by an abstract, maximum 200 words.
- References to published literature should be quoted in the text in the following manner: [1], and grouped together at the end of the paper in numerical order.
- Submission of a manuscript implies that the paper has not been published and is not being considered for publication elsewhere.
- Once a paper has been accepted for publication in this journal, the author is assumed to have transferred the copyright to the Virginia Mathematics and Science Coalition.
- There are no page charges for the journal.

Copy editor: E. Faircloth

(Contents continued from back cover)

PART II: Regular Journal Features

CONTENTS Volume 5

PART I: VCEPT – Virginia Collaborative for Excellence in the Preparation of Teachers

(Contents continued inside)